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Integrated nutrient management in poplar-eucalyptus based sustainable agroforestry system

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Contents

Summery

The three years efforts made with the objective of finding out optimum nutrient needs drawn from chemical and biological sources have yielded many strong recommendations. Soil biological health have improved due to inoculation of suitable application of microorganisms and the reflection of this improvement was clearly evident through increment in yield and biomass. When the cost economics was taken into accounts it was further justified and maximum cost benefit ratio became evident where biofertilizer inoculated microorganism was applied in the agro forestry model. This clearly strengthen the future need to carryout multi location validation trials in a national network for eventual recommendations those could be beneficial to farming community and the environment.

1 Introduction

India produced 210 MT of food grains during 2000-2001. India's population is expected to increase by 150 million 2500 AD and will need 325 MT of food grain. At the current food production level, India will have to achieve an additional food production of 5 MT per annum as against 3.1 MT per year achieved over the past 40 years. The land holding per capita is narrowed rapidly from 0.48 ha in 1951 to 0.20 ha in 1981 and it is expected to go down drastically due to urbanization and industralization. The increasing demand for agricultural produce is currently being fulfilled through the abundant use of fertilizers and pesticides. The consumption of pesticides, herbicides, and fertilizers went up from 0.08 MT , 0.0048 MT and 12.56 MT in 1990-91 to 0.98 MT , 0.0081 MT and 16.91 MT respectively in 1997-98. An increased use of fertilizers has helped the country in achieving self-sufficiency in food grain production. However, their excessive use has polluted the environment and has caused a decline in soil productivity. There is evidence to show that many of the chemicals used in fertilizers and pesticides bring about alterations in the biological ecosystem and affect non-target organisms in the soil. Further, greenhouse gases (NO) emanating from fertilizers also damage the ozone layer.

The recent energy crisis, depletion of non-renewable resources and decrease in subsidy on fertilizers by the government have all become a matter of great concern to the government, fertilizer industry, and farmers. The import of fertilizers to meet the growing demand has posed a heavy foreign exchange burden on the country.

There is need to look for an alternative renewable source of nutrient supply which can support crop production in a sustainable manner. The integration and optimization of mineral fertilizers, organic manure, crop residues, manipulation of biological fertilizers/micro-organisms and changing the cropping pattern will certainly achieve sustainability in food grain production.

Integrated nutrient management is one of the most important aspects of sustainable agriculture. It involves balancing of fertilizer-cum-organic recycling, combined use of organic manure and chemical fertilizers and exploiting biological fertilizers while taking a holistic view of soil fertility and the crop management system. Alternatives to curtail the use of chemical fertilizers are available in nature, which encourage the use of biofertilizers in combination with organic farming to achieve sustainability in plant production.
Hence, there is need to look for an alternative source of nutrients which can support crop production in sustainable manner.

Conservation and augmentation of mycorrhizal fungi and other biofertilizers along with organic manure, and integration with inorganic fertilizers are all important approaches to sustaining plant productivity.

2 Ingredient nutrient management in poplar-eucalyptus-based sustainable agro-forestry system

Objectives

The objectives set forth in the current proposal were to achieve sustainability in crop production by:

- Evaluation of the performance of economically important plant species in agroforestry operations under an integrated nutrient supply system (optimization of balanced nutrient status).

- Optimization of the levels of chemical fertilizers, organic manures (FYM/compost), biofertilizers and related beneficial microorganisms for enhanced nutrition to plants.

- Testing of groups of microorganisms viz., PSBs, mycorrhiza, rhizobium etc., for efficient nutrient supply to plants and improved availability of these nutrients in soil.

Experimental sites

Site 1 – TERI's experimental station

The site was located in a semi arid zone, at Gual Pahari, in Haryana, India (35° 28' N and 77° 12' E) 255 m above mean sea level. The site was not in productive use and measured approximately one acre, approachable from the main road and fenced with barbed wire (The soil type was sandy loam (0-30 cm depth) Hypothermic Typic Haplustalf). The nutrient characteristics of soil at zero time, water and FYM used are presented in Tables 1a and b.

Site 2 – Farmer's field

The site was located in Sohna district of Haryana State and was around 25 km away from TERI's field laboratory. The site measured around 2.5 acres of which about 0.805 acre was under livestock production while the remaining area was

used for field trials. The site has been under cultivation for three years and is irrigated. The soil type was the same as for site 1.

Cropping system

Poplar-Eucalyptus agro- forestry system intercropped with wheat-pulse rotation. During the project tenure two rotations of wheat-pulse were followed.

Materials and methods

At both sites field trials on wheat and pulses were conducted using the split plot completely randomized block design replicated three times. Experimental design and layouts for both the sites is given in Annexures K–Q.

Tree species

Populus deltoides was planted in the site across all the treatment plots.
Eucalyptus tereticornis was planted on the boundary.

Spacing: Poplar (PxP = 5.5 m; RxR = 3 m)
Eucalyptus (PxP = 6 m)

First year rotation (wheat-mung bean)

Crop	:	Wheat (cultivar - UP 2338)
Experimental design	:	RBD (factorial 4 x 2)
Replication/blocks	:	3
Treatments	:	8
Fertilizer levels	:	4
AMF inoculation	:	2
Total treatments	:	Fertilizer levels ± AMF; 4 x 2 = 8 treatments
No. of main treatment plots/block	:	4 (fertilizer levels)
No. of subplots/plot	:	2 (VAM inoculation)
Total no. of experimental plots or units	:	8 x 3 = 24

After harvesting the wheat field trials on mung bean were conducted on both sites using the same design as used for wheat trial, the treatment plots of fertility levels were retained as such after the harvest of wheat. AM fungi and uninoculated sub plots under each fertility was further splitted by rhizobium inoculations. Each plot was replicated three times.

The following treatments were applied:

Crop : Mung bean (cultivar HUM-1)

Experimental design	:	RBD split plot (Factorial 4 x 2 x 2)
Replications/blocks	:	3
Treatments	:	16 (4 fertilizer levels ± AMF ± Rhizobium)
Fertility levels	:	4
AM Inoculation	:	2
Rhizobium inoculation	:	2
No. of main treatment plots/block	:	4 (fertilizer levels)
No. of sub plots per main plot	:	2 (VAM inoculation)
No. of plots per sub plot	:	2 (Rhizobium inoculation)
Total no. of plots per fertility level plot	:	4
Total no. of plots per block	:	4 x 2 x 2 = 16
Total no. of plots or experimental units	:	16 x 3 = 48

Procurement of Triticum aestivum (wheat) seeds

Seeds of wheat cultivar UP-2338 were obtained from the National Seeds Corporation, Gurgaon.

Procurement of mung bean seeds and rhizobium

The mung bean (cultivar HUM-1) seeds were procured from the National Seeds Corporation, I A R I Campus, New Delhi.

The rhizobium culture strain mung bean was procured from the division of microbiology, IARI, New Delhi.

Procurement and multiplication of plant germplasm

Eucalyptus tereticornis

Seeds of *E. tereticornis* were obtained from a single elite (plus) tree situated in the seed orchard at the Tata Energy Research Institute's field station, at Gual Pahari. Germination of seeds was done by mixing the seeds with 200 g sterilized fine river sand (sieved through 60 BSS mesh sieve) in a tray filled with fine sand. The sand was moistened with Hoagland's nutrient solution (Hoagland and Arnon, 1938) regularly until the seedlings grew 1 cm tall. Two seedlings were planted and then thinned to one per poly bag.

Populus deltoides

A one-year-old vegetatively propagated starter entire transplant (ETPs) clone G-48 was used for plantation. The mass production of ETPs was achieved by the

vegetative propagation method using cuttings of 9" length and 1 cm diameter. These were prepared and planted (already drenched/treated with 0.02% chloropyriphos 20 EC) in holes (leaving 0.5 to 1.0 cm of the plant above ground level) at a spacing of 60 x 80 cm in beds (see annexure). After one year the plants were dug out and transplanted at the site along with intact roots.

Preparation of AM inoculum and infectivity bioassay

The mixed indigenous AM fungal inoculum containing native propagules of *Glomus, Gigaspora* and *Scutellospora spp.* was obtained by isolating the propagules (Gerdemann and Nicolson, 1963) from the wasteland site. The crude inoculum (spores/sporocarps, hyphae and root bits) with sterilized soil of the same site (solarized at 56°C ± 3°C for eight days by covering with a white translucent polyethylene sheet). *Sorghum vulgare.* L. was grown continuously for two cycles (each cycle 16 weeks) in a green house at 32°C ± 5°C, after which the shoots of the plants were removed. The soil and roots left in the pots were dried in shade for three weeks. The air-dried mass from all the pots was homogenized thoroughly (the roots were cut into smaller pieces before mixing).

The inoculum at each harvest was subjected to a bioassay to assess the number of infectious propagules. Inoculum potential was expressed as the number of propagules per gram of substrate using a bioassay (Gaur et al. 1998) with sorghum. The inoculum was distributed in a series of plastic pots (7 cm height and 5 cm diameter) containing 100 g of inoculum in each pot. A pot containing unsterilized soil alone was also maintained to determine the background level of infectious propagules present in the soil. Seeds of sorghum were graded by weight (0.03 g – 0.04 g) and surface sterilized with 10% H_2O_2 for five minutes. Subsequently, the seeds were washed repeatedly with sterile water and kept for germination on moist cotton layers in petriplates at 30°C for 48 hours. Eight seedlings were placed in each pot and maintained in a greenhouse at 35°C ± 5°C with 60% relative humidity. The pots were watered at regular intervals so as to maintain the soil moisture content (gravimetrically) at approximately 60% of the water holding capacity and harvested after 14 days.

Assessment of primary entry points/infectious propagules

At harvest, the shoots were cut and the root system with intact soil was dipped in 500 mL Calgon (sodium hexametaphosphate, 2%) solution. After 8 hours the

soil was gently dispersed and Calgon solution was drained out. It was then replaced with fresh water. This was repeated 3-4 times until the roots became clear and little debris was seen attached to them. The roots were then stained as described by Phillips and Hayman (1970).
To analyze the random distribution of infection units, the root length was determined by spreading the complete root system in a gridded (2 x 2 cm) petriplate. The number of intersects across the gridlines was counted and the root length calculated according to the Tennant's method (1975), i.e.,
Root length = Number of intersects x 11/14 x grid size

The roots were then chopped into 1 cm pieces and 50 root bits per replicate were selected randomly and mounted on glass slides consisting lactoglycerol drops and observed at a magnification of 20X under a compound microscope (Gallen III, Leica, Cambridge, UK) attached to a CCD camera and an image analyser system (Leica, Switzerland) controlled by Quantimet 500 option. The total number of entry points in these pieces was counted and the number of entry points formed per cm of root length was assessed. Multiplying this value to the root length, the total number of entry points formed in the whole root system was calculated.

Field preparation, soil sampling and soil bio-chemical analysis

The sites were prepared by repeated ploughing and planking in order to achieve a fine tilth. Coarse stones and stubs were removed. Soil samples were drawn using a soil auger at a depth of 15 and 30 cm from 5-6 random spots strictly in a zigzag pattern. The litter was removed from the surface without disturbing the soil much. Samples were mixed thoroughly from different spots of the field and three composite samples were made by the quartering method. The site was harrowed (12" depth) and recommended doses of FYM were applied to the respective treatment plots and were kept for one week or until sowing of wheat.

Processing of soil samples

Soil samples were air-dried at 20-25^{o}C and with a relative humidity of 20-60%, to prevent microbial changes Large lumps of moist soil were broken by hand and spread on paper in a room free of fumes, dust etc. Coarse concretions, stones and pieces of macro-organic matter (root, leaves and other vegetative material) were picked out. After air-drying, the samples were passed through a 2-mm sieve and were processed for the soil chemical analysis.

The samples (without air-drying) for microbial population were subjected to microbial analysis.

Analysis of soil samples at zero time

The samples were analyzed for the following parameters:

Soil chemical parameters:

- Soil pH and electrical conductivity
-Available phosphorus and potassium
-Organic carbon and total nitrogen
-Total and available zinc, manganese, iron and copper

Biological parameters:

-Total culturable microbial count
-Soil dehydrogenases activity
-Mycorrhizal propagule density

Analysis of soil chemical parameters

Soil pH and electrical conductivity were measured (in a 1:2.5, soil to water sample) using digital pH and EC meters. Available phosphorus in soil was determined by extraction with sodium bicarbonate for 30 minutes (Olsen et al. 1954). Organic carbon was estimated colorimetrically (Datta et al.1962). Total nitrogen was analyzed in the form of NH^{+}_{4}–N by the distillation and titration method (Bremner, 1960). The total micronutrient concentration in the samples was determined by digesting the samples in a microwave digestion system (MARS, Unichem Corp., USA) with HF for ten minutes and measured with an atomic absorption spectrophotometer (AAS, Analytik Gena) using the flame mode. The available forms of Fe, Zn, Cu, and Mn were determined by extracting the samples in DTPA solution (Lindsay and Norvell, 1978).

The concentration of the metal cations was determined using calibration curve prepared with a standard solution or read directly from instruments equipped with a microprocessor.

Analysis of biological parameters

The total microbial population was determined by a serial dilution technique (Clark, 1965a). Aliquots from different dilutions were plated on Luria Agar

medium (Premix Hi media make Cat. No. M 557) separately and incubated at 25°C. After 12 hours the colonies were counted from each dilution.

The soil dehydrogenases activity, which involves the colorimetric determination of TPF, produced from the reduction of TTC in substrates/24 hours. (Cassida et al. 1964) was determined in all the samples.

The mycorrhizal spores were counted by isolating the spores using the wet-sieving and decanting method (Gerdemann and Nicolson, 1963) and healthy spores were counted in a circular disc/plate under the stereo zoom. The mycorrhizal infectivity potential of the soil was determined using the bioassay (Gaur et al. 1998)

Digging of pits and termite treatment

Pits 1.5 feet diameter and 3 ft deep were dug using a soil screw auger at a spacing of 5.5 m R×R and 3 m P×P for poplars. For Eucalyptus plantation pits of similar dimensions were dug on the boundary at a spacing of 5 m × 5 m. Each pit was treated with chloropyriphos 20 EC by the soil drenching method as a prophylactic measure to control termite attack.

Planting of poplar and eucalyptus

After two weeks of pesticide treatment plantation was carried out. One year-old ETPs produced at the experimental site were transplanted straight into pits covered and compacted with soil. Three month old Eucalyptus seedlings were transplanted into pits on the boundary. Both the tree species were inoculated @ 400 propagules of indigenous mycorrhizal fungi during transplanting.

Fertilizers and manuring for crops

Following fertilizer and manure doses were applied for wheat crop at both the sites.

F1	=	Nitrogen 100 kg/ha; phosphorus 50 kg/ha; potassium 40 kg/ha and FYM 20 tonne/ha (recommended level)
F2	=	Nitrogen 100 kg/ha; Phosphorus 25 kg/ha; potassium 40 kg/ha and FYM 20 tonne/ha
F3	=	Nitrogen 100 kg/ha; phosphorus 50 kg/ha; potassium 40 kg/ha and FYM 40 tonne/ha
F4	=	Nitrogen 200 kg/ha; phosphorus 100 kg/ha; potassium 80 kg/ha and FYM 20 tonne/ha

Mung bean crop

Following fertilizer and manure doses were applied at both the sites.

F1	=	Nitrogen 20 kg/ha; phosphorus 50 kg/ha; and FYM 8 tonne/ha (recommended level)
F2	=	Nitrogen 20 kg/ha; phosphorus 25 kg/ha; and FYM 8 tonne/ha
F3	=	Nitrogen 20 kg/ha; phosphorus 50 kg/ha; and FYM 16 tonne/ha
F4	=	Nitrogen 40 kg/ha; phosphorus 100 kg/ha; and FYM 8 tonne/ha

The diammonium phosphate (DAP) fertilizer was used partly as a source of P and partly N. The dose of the other inorganic fertilizer i.e., potassium was applied in the form of ureate of potash (MOP) mixed throughout the soil in each treatment plot before sowing. Nitrogen was applied in two split doses; half of the dose was applied at the time of planting in the form of DAP and the remaining half after one month in the form of urea. No other nutrients and chemicals were applied during the experiment.

Well-rotted FYM procured from a nearby village was applied to the respective treatment plots and mixed two weeks before fertilizer application.

Second year wheat-urd rotation

At both the sites where wheat was grown, the following treatments were tested: At the Gual Pahari site, the four treatment plots which were used for mung bean within a fertilizer application dose, were further split into four sub-sub plots leaving the same plot as one of the four plots. The other three plots were used for azospirillium 1, azospirillium 2 and phosphate-solubilizing bacterial inoculations. In the farmer's field the treatments were same as used for the first year wheat experiment.

After wheat harvest, the urd was grown only at TERI'S experimental site using the same treatment plots. Rhizobium and mycorrhiza inoculations were done in the corresponding plots of all the fertilizer doses. All the other plots were maintained as such to see the residual effect of previous inoculations on urd.

Sowing of mung bean, urd, wheat, and application of AM fungi, rhizobium, phosphate solubilizing bacteria and Azospirillium biofertilizers.

The seed sowing of mung bean and urd was done by tractor-drawn seed drill. Seeds were first inoculated by mixing the rhizobium inoculant with a small quantity of water and then drying the seeds in the shade.

The mycorrhizal inoculum along with seeds was filled in the drum and applied during sowing. The dose of mycorrhizal inoculum was calculated on the basis of area to ensure that each plant got 20 propagules.

The seed sowing of wheat was done by tractor using seed drill. Seeds were first inoculated by mixing the PSBs and Azospirillium inoculants with a small quantity of water and then drying the seeds in the shade.

The mycorrhizal inoculum along with seeds was filled in the drum and applied while sowing. The dose of mycorrhizal inoculum was calculated on the basis of area to ensure that each plant got 25 propagules.

After-care, harvesting and measurements

Standard agronomic practices such as regular hoeing, irrigation, and weeding were followed. Just after sowing and germination, the whole site was covered with bird-scaring ribbons to protect the crop from birds. The crop was irrigated four times for mung bean and urd, and six times for wheat covering all the critical stages of growth.

At harvest, ten plants were randomly selected and harvested from each treatment plot (constitutes one replicate) to record growth and mycorrhizal parameters. The grain yield was calculated on basis of area.

Parameters recorded

At harvest the following parameters were recorded

Soil chemical parameters

- Soil pH and electrical conductivity
- Available phosphorus and potassium
- Organic carbon and total nitrogen
- Total and available zinc, manganese, iron and copper

Biological parameters

	Criteria	*Plant 1*	*Plant 2*
2 5	Debt-service coverage ratio		
3.0	**Human Resources (SEB-wise)**		
3 1	No of engineers/ Skilled technicians/Unskilled workers per plant		
4.0	**Others (SEB-wise)**		
4 1	Restructuring/reform status		
4 2	Credibility among FIs, like WB, KfW, ADB, PFC, IDBI, etc.	.	

3 Results

First rotation (1999-2000) Wheat (Site1)

Effect of fertilizers, manures, and mycorrhizal inoculation

Growth parameters of wheat

The growth data are presented in Table 6. The grain yield was on a par with all the applied levels of fertility. The maximum grain yield (29.62 q/ha) was recorded in the AM-inoculated treatment plots at the recommended NPK level with double the dose of FYM which is significantly higher than the recommended fertility levels. The double dose of NPK applied did not produce a significantly higher yield when compared with a single dose of fertilizers and double dose of FYM.

The maximum straw yield (38.93 q/ha), although statistically on a par was found in plots treated with the double the dose of recommended NPK + 8 tonnes FYM followed by recommended NPK + 16 tonnes FYM applied plots.

The mycorrhizal inoculated plots at all the applied fertility doses produced higher weights (weight of 1000 seeds). A significantly higher weight (48.93 g) was recorded in the inoculated plots of recommended NPK with double dose of FYM. The weight did not vary significantly in any of the applied levels tested. The mycorrhizal inoculated plots at all the applied levels of fertility showed the maximum number of tillers per plant. A comparatively large number of tillers (5.0/plant) was produced in the inoculated plots at recommended NPK+ 16 tonnes FYM level.

Overall the growth parameters were influenced significantly by mycorrhizal treatment at recommended NPK+ 16 tonnes FYM application.

Higher concentrations of plant P and N were recorded in mycorrhizal plots irrespective of fertility dose applied. However, significantly higher concentrations of N (0.87%) in plant tissues were recorded in the inoculated plants grown at recommended NPK+16 tonnes FYM when compared to all other

treatment combinations tested. The phosphorus concentration differed significantly in the inoculated plots at all the applied fertility doses.

Soil biochemical parameters

The soil pH and EC did not differ significantly in all the treatment combination plots. Higher removal of macro nutrients (NPK) and organic carbon was observed in the mycorrhiza-treated plots at all fertility levels when compared to their uninoculated counterparts (Table 2). A similar trend was also observed in the micronutrient profile of Zn, Mn and Fe. Copper was below detection limits.

Soil microbial parameters

The data in Table 4 show that there was no significant trend in the total culturable microbial count and dehydrogenases activity in all the treatment plots. However, the dehydrogenases activity was slightly higher in the inoculated plots than in their uninoculated counterparts.
The maximum number of infectious propagules was found in the inoculated plots (6.81) at recommended NPK+16 tonnes FYM followed by inoculated plants grown at half the recommended level of P+8 tonnes FYM.

The maximum (17.44%) percent root length colonized by AM was observed in the plants grown at recommended NPK+ 16 tonnes FYM followed by plants grown at half the recommended level of P + 8 ton FYM (15.32%).

Wheat (Site 2)

Effect of fertilizers, manures, and mycorrhizal inoculation

Growth parameters of wheat

The growth data are presented in Table 7. The grain yield differed significantly among the applied levels of fertility. The maximum grain yield (28.48 q/ha) was recorded in the double dose of NPK+8 tonnes/ha treatment plots followed by plots fertilized with the recommended level of NPK+16 tonnes FYM. The inoculated plots had higher yields when compared to their counterparts. Higher yields (28.64 q/ha) was found in inoculated plots of recommended NPK+16 tonne FYM (Table 7).

The straw yield, weight of 1000 grains, number of tillers per plant showed the same trend as at Site 1. The mycorrhizal-inoculated plots at all the applied fertility levels produced higher weights (weight of 1000 seeds). Significantly

higher weight (47.55 g) was recorded in the inoculated plots of recommended NPK with double dose of FYM. The weight did not vary significantly among the fertility levels tested. The mycorrhizal-inoculated plots at all the applied levels of fertility showed maximum number of tillers per plant. A comparatively larger number of tillers (5.06/plant) was produced in the inoculated plots at recommended NPK+ 16tonFYM level.

Overall the growth parameters were influenced significantly by mycorrhizal treatment at recommended NPK+ 16 tonne FYM applied level.

The higher concentration of plant P and N was recorded in mycorrhizal plots irrespective of fertility level. The maximum phosphorus concentration response was recorded in the inoculated plants grown at half P level.

Soil biochemical parameters

The soil pH and EC did not differ significantly among all the treatment combination plots. Maximum removal of macronutrients (NPK) and organic carbon was found in the mycorrhiza-treated plots at all the fertility levels (table 3). The micronutrient profile showed the same trend as at Site 1.

Soil microbial parameters

The data in Table 5 show that there is no significant trend in the total microbial count and dehydrogenases activity in all the treatment plots. The maximum number of infectious propagules was found in the inoculated plots (8.65) at recommended NPK+40 tonne FYM followed by inoculated plants grown at half the recommended level of P+8 tonne FYM.

The maximum root length colonized by AM w (14.92%) as observed in plants grown at recommended NPK+16 tonne FYM followed by plants grown at double the dose of recommended level of NPK+8 tonne FYM (11.66%).

Growth parameters of tree species

The poplar plants were planted at both the sites during the month of February 2000. The growth parameters in terms of girth at breast height (GBH) and height were recorded at planting time and during November 2000. The data we presented in Table 8. The GBH and height was not found to be significantly different among any of the treatments tested. However, the growth improved significantly over the zero time at both the sites.

Mung bean (Sites 1and 2)

Growth and nutrients

The plants inoculated with mycorrhiza or rhizobium singly or in combination at F3 (double dose of FYM + single dose of applied fertilizers) and F4 (double dose of fertilizers + single dose of FYM) fertilizer doses produced significantly higher grain yields when compared with F1 (single dose of applied fertilizers + single dose of FYM) and F2 (single dose of N, K and half dose of P applied levels + single dose of FYM). The maximum grain yield was recorded in inoculated plots of F4 dose but it was statistically on a par with the grain yield obtained in F3 plots. The weight of 100 seeds grain and number of pods/plant were higher in F3 and F4 plots but none of the treatments was significantly different when compared to other fertilizer dose plots. The shoot height was also found to be higher in F3 and F4 plots when compared to other fertilizes doses.

All inoculated plants irrespective of fertilizer dose showed significantly higher concentrations of phosphorus in the shoots and nitrogen in nodules and plants when compared to uninoculated plants (Table 10).

At the badshahpur site all the inoculated plots irrespective of fertility dose produced significantly higher grain yields when compared to the grain yields obtained in their respective uninoculated plots. The same trend was observed with the weight of 100 seed grains. Overall, all the treatments allocated in F3 and F4 plots had higher yields than the F1 and F2 plots. Within a particular fertilizer dose, dual inoculation with AMF and rhizobium produced a larger number of pods/plants and greater plant height than uninoculated plants. A similar profile was obtained with increased concentrations of shoot P and total N compared with the uninoculated counterparts. The plants grown at F3 and F4 fertilizer doses had a higher uptake of P and N than plants grown in the F1 and F2 plots (Table 11).

Soil nutrient and microbial profile

At both the sites the soil pH and EC were not influenced significantly due to inoculations and fertilizer doses. All the fertility doses showed higher removal of available soil phosphorus in AMF- inoculated plots followed by AMF+rhizobium plots, when compared to uninoculated plots. This higher removal was more evident in F3 plots. A similar trend was also observed in at the Badshahpur site (Tables 12 and 13).

The percent root length colonized by AMF showed highest colonization in the AMF inoculated plants grown at F3 dose. The AMF colonization enhanced irrespective of fertilizer doses due to rhizobium inoculation. The double dose of fertilizer application did not reduce the colonization at both the sites. The soil dehydrogenases was also found to enhance due to inoculations at all the fertility doses. The uninoculated plots showed significantly lower soil dehydrogenases than the inoculated plots. The fertilizer application doses did not influence the dehydrogenases (Table 12 and 13).

Second rotation (2001-2002) Wheat (Sites 1 and 2)

Soil nutrient status

Soil reaction (soil pH) and electrical conductivity (EC) did not differ significantly over a period of two year rotation though, conductivity of soluble salts improved due to treatment effects (0.16 to 0.40) (Table 1 and Tables 15–19; 29–32). Organic carbon analyzed at harvest showed maximum improvement in all the AMF, PSBs, Azospirillum-inoculated plots fertilized at F3 that were also inoculated with mycorrhiza and rhizobium (Tables 15–19; 29–32, and 37–38).

Availability of major nutrients was analyzed at the end of the second year of wheat harvest considering the residual effect of inoculations of previous crop. The results indicated the largest percent increment in nitrogen, phosphorus, and potassium (Tables 15–19, 29–32, and 37–38) in PSBs-inoculated plots fertilized with recommended dose of fertilizers given double dose of FYM (F3) and previously inoculated with mycorrhiza+rhizobium of mung bean crop. The mycorrhiza and mycorrhiza+rhizobium inoculated plots of the preceding crop showed the maximum increment in N, P, K irrespective of fertility level (Tables 15–19; 29–32).

A significant improvement in soil nutrient profile at the badshahpur site was also recorded in AMF-inoculated plots at the F3 level (Table 37) with maximum availability of NPK.

Soil microbial status

The inoculum potential of mycorrhizal fungi (AMF) increased significantly in all the inoculated plots. Maximum increment was recorded in the inoculated plots at F3 fertility level (Tables 20–23). The background level of AMF also improved in F3 plots.

The soil dehydrogenases activity and total culturable microbial count was influenced by fertility level and previous inoculations. Maximum count was recorded in inoculated plots (current and past) at F3 level (Tables 20–23). The micronutrient level was also found to be influenced significantly by inoculations. Maximum level of micronutrients (Zn, Mn, Fe, and Cu) was recorded in the PSBs-inoculated plots irrespective of fertility level (Tables 31 and 32). The total culturable microbial count at the Badshahpur site did not differ significantly in the treatment plots, however, soil dehydrogenases were maximum in the inoculated plots of F3 level (Table 38).

Yield and uptake of nutrients

Wheat yield of grain and straw in the second year was influenced significantly by inoculations and fertility levels. The plots fertilized at F3 irrespective of inoculations harvested the maximum number of tillers/plant, grain and straw yield/ha (Tables 24–28). A similar trend in yield was reflected at the Badshahpur site (Table 39). When compared to inoculations, plots inoculated with PSBs followed by AMF and Azospirillum produced significantly higher yields over the uninoculated controls (Table 28).

The nitrogen, phosphorus and micronutrient uptake a in shoots of wheat was improved due to inoculations at all the fertility levels (Tables 24–27). Maximum nitrogen and phosphorus uptake was recorded in the inoculated plants grown at the F3 level at both the sites. Among inoculated plants at the Gual Pahari site, PSBs-inoculated plants followed by AMF and Azospirillum showed maximum micro-nutrient uptake when compared to uninoculated plants (Tables 24–27). There was a significant difference in nutrient uptake of inoculated and uninoculated plants of previous and current inoculations.

Biomass profile of poplar

The poplar height and girth at breast height (GBH) were significantly increased over zero time (Table 40). The effect of fertility level on poplar biomass was evident based on the profile recorded in the 20th month. There is an upward trend in biomass in the F3 fertility level when compared to other applied levels.

Nutrient budgeting for available macronutrients

Application of inorganic fertilizers in combination with manure and biofertilizer treatments after 2 years showed a positive/gain trend for all the major nutrients

(Table 36). The inoculated plots at a particular fertility level showed less removal of nutrients compared to their uninoculated counterparts.

Cost economics

Cost economics of wheat due to inoculations at various fertility levels showed the maximum incremental cost benefit ratio (ICBR) at F3 level inoculated with PSBs and AMF together (AMF+Rhizobium previously inoculated plot) (Table 35).

When economics were calculated involving a poplar-based agroforestry system taking one year wheat pulse rotation into consideration, higher returns were obtained in the inoculated plots irrespective of fertility levels (Table 41). The poplar-based wheat-pulse system was found to be more beneficial (higher B/C ratio) when compared to conventional (wheat-pulse rotation) systems (Tables 35–41).

Urd (2001-2002)

Urd was grown only at Site 1.

Soil and nutrient status

Soil reaction (soil pH) was not influenced by fertilizer application and inoculation done over two rotations of wheat-pulse. The soil pH ranges from 7.10 to 7.35. The electrical conductivity (the conductivity of soluble salts) significantly improved in all the inoculated plots when compared to uninoculated plots (Tables 42–43). The organic carbon in soil analysed at harvest followed the trend of the preceding rotation which indicates an improvement in the plots applied with double dose of FYM along with fertilizers (F3) when compared to organic carbon level in the plots that received a single dose of FYM (Tables 42 and 43).

The availability of major nutrients analyzed at the end of the second year of the pulse (urd) harvest considering the residual effect of inoculation made during the previous and current crop indicates that there is high removal of available phosphorus and potassium at all the fertility levels of inoculated plots when compared to uninoculated plots. The nitrogen and micronutrient profile did not follow any trend (Tables 44 and 45). There is a higher uptake of iron and manganese in the plants grown in F3 plots when compared uninoculated plants.

The micronutrient profile in other fertilizer doses did not show a significant difference (Tables 44 and 45).Inoculated plots at F3 level showed higher availability of nutrients which reflected in terms of higher uptake of P in shoots compared to plants grown in uninoculated plots. All the inoculated plots particularly rhizobium plots had higher concentrations of nodule nitrogen when compared to uninoculated plots (Table 48).

Soil microbial status

The soil dehydrogenases and cultural microbial population determined at harvest was found to be influenced by fertilizer application and type of inoculation. A higher count of culturable microorganisms was recorded in all the inoculated plots when compared to uninoculated plots (Table 47).

Growth and yield

A significantly higher number of pods/plants and grain yield was recorded in the plots fertilized with double the dose of FYM when compared to the fertilizer doses where FYM application was low. All the inoculated plots produced higher grain yield and pods/plant than in the uninoculated plots (Table 48).

Nutrient budgeting

Application of fertilizers, manures, and various inoculations made during past two rotations of wheat-pulse showed a positive trend for all the major nutrients. The plots which received double doses of FYM along with inorganic fertilizers showed a higher gain of macronutrients and was on a par with the nutrient gain received in the higher dose of inorganic fertilizers (Table 49).

Table 1 Bio-chemical characteristics of soil at the two experimental sites at zero time

Macronutrients and chemical *parameter*	*Site 1*™	*Site 2*
pH (1: 2.5 soil.water)	7.38 ± 0.29	7.12 ± 0.13
Electrical conductivity (dS/m)	0.16 ± 0.013	0.59 ± 0.021
Available phosphorus (ppm)	3.78 ± 0.98	6.48 ± 0.91
Potassium (ppm)	92.30 ± 5.11	117.3 ± 9.30
Total nitrogen (%)	0.09 ± 0.002	0.17 ± 0.003
Organic carbon (%)	0.52 ± 0.03	0.63 ± 0.04
Micronutrients		
Copper (total)	5.16 ±0.19	2.7 ± 0.01
Copper (DTPA)†	0.21 ± 0.001	0.4 ± 0.002
Iron (total)	9926.37 ± 112.3	8726.83 ± 97.34
Iron (DTPA)	24.7 ± 1.17	14.18 ± 1.13
Manganese (total)	159.05 ± 4.03	189.14 ± 6.28
Manganese (DTPA)	9.03 ± 1.03	5.07 ± 0.07
Zinc (total)	32.56 ± 2.46	28.12 ± 0.06
Zinc (DTPA)	5.65 ± 0.03	5.82 ± 0.04
Microbial parameters		
Dehydrogenases (µg/g/24 hours)	6.7 ± .43	11.2 ± 0.74
Total microbial count (c.f.u/g)	1.8×10^4	3.06×10^4
Total phosphate solubilizing microorganisms (c.f.u/g)	4×10^3	4.68×10^3
Mycorrhizal propagule density	1.23 ± 0.06	0.098 ± 0.02

™ Experimental sites Site 1= Gual Pahan, Site 2= Badshahpur farm land

• Means are average of three replicates; ± standard deviation of mean

† DTPA- Diethylene triamine pentaacetic acid extractable Fe,Cu, Mn and Zn in soil

Table 1a Chemical characteristics of water collected from two different sources

Parameter	*Gual Pahan Irrigation water*	*Badshahpur farmer's field water*	*Farm yard manure (FYM)*
PH	7.34	7.18	7.79
Electrical conductivity (dS/m)	0.36	0.98	3.82
Nitrogen (%)	–	–	0.95%
Organic carbon (%)	–	–	4.22
Ca + Mg (me/L)	–	4.08	–
HCO_3-- (me/L)	4.16	2.12	–
Copper (ppm)	BDL*	BDL	–
Iron (ppm)	0.027	0.031	–
Lead (ppm)	1.71	1.09	–
Manganese (ppm)	BDL	BDL	–
Nickel (ppm)	0.001	0.006	–
Zinc (ppm)	BDL	BDL	–

* Below detectable level

Table 2 Effect of fertilizer/manure integrated with indigenous mycorrhiza on soil biochemical characteristics analyzed at harvest grown at Gual Pahari site

		Macronutrients and chemical parameters						Micronutrients			
Treatment		pH	EC* (dS/m)	N %	Olsen P (ppm)	K (ppm)	OC (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
F1	Inoculated	7.29 a	0 343 a	0.165 c	6.54 bc	87.3 f	0.33 d	27.9 b	234.9 b	8813.8 b	BDL
	Uninoculated	7.51 a	0.336 a	0.260 b	6.28 c	127.3 a	0.70 a	45 a	269 2 a	9932.1 a	BDL
F2	Inoculated	7.30 a	0.223 a	0.294 b	7.09 bc	103 6 c	0 35 d	21.8 cd	153.6 c	6101.5 e	BDL
	Uninoculated	7.67 a	0.206 a	0 276 b	7.68 bc	100 3 c	0 51 b	22.3 cd	235.7 b	7824 8 c	BDL
F3	Inoculated	7.48 a	0.200 a	0.255 b	6.84 bc	83 f	0 43 c	18.7 d	123 6 de	5974 1 f	BDL
	Uninoculated	7.51 a	0.250 a	0.275 b	11.52 a	97.3 cd	0.43 c	21.1 cd	160.7 c	6232.6 d	BDL
F4	Inoculated	7.28 a	0.266 a	0.340 ab	8.60 abc	93.6 de	0.34 d	29.8 b	114 6 e	4007.4 h	BDL
	Uninoculated	7.41 a	0.240 a	0 394 a	9.62 ab	116.6 b	0 66 a	23 9 c	126.4 d	5352 g	BDL
LSD (0.05)		0.399	0.171	0 085	2.97	6.73	0.062	3 32	11.13	7.84	-

- electrical conductivity, Means are average of three replicates; LSD= least significance difference, the means followed by same letter did not differ significantly by DMRT

Table 3 Effect of fertiliser/manure integrated with indigenous mycorrhiza on soil biochemical characteristics analysed at wheat harvest grown at Badshahpur site

		Macronutrients and chemical parameters						Micronutrients			
Treatment		pH	EC* (dS/m)	N %	Olsen P (ppm)	K (ppm)	O.C (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
F1	Inoculated	7.81 a	0.240 ab	0.244 ab	10 56 b	93.6 c	0.80 bc	19.2 c	221.3 b	7609.3 c	BDL
	Uninoculated	7.28 cd	0 220 d	0.268 ab	14.27 a	97.6 c	1.03 a	23.8 ab	239.1 a	8709.5 a	BDL
F2	Inoculated	7 43 bcd	0.286 c	0.227 b	6.76 c	126 3b	0.34 d	20.8 c	206.8 c	7341 d	BDL
	Uninoculated	7.22 d	0.260 cd	0.257 ab	8.92 bc	148 a	0 95 ab	23.9 ab	224.4 b	7893 9 b	BDL
F3	Inoculated	7 64 ab	0 453 a	0.209 b	7 44 c	126 b	0.72 c	20 4 c	117.1 d	6651.4 f	BDL
	Uninoculated	7.57 abc	0.236 cd	0.225 b	8.76 bc	157.6 a	0.95 ab	23 9 ab	126.2 d	6840.6 e	BDL
F4	Inoculated	7.35 bcd	0.350 b	0 228 b	14.5 a	125.3 b	0 81 bc	22.7 b	95.9 f	4420 9 h	BDL
	Uninoculated	7.5 abcd	0.226 cd	0 307 a	11.02 b	131 3 b	1.1 a	24.9 a	106 1 e	5003.3 g	BDL
LSD (0.05)		0.31	0 05	0.06	2.53	10.75	0.16	1.91	9 9	11.39	-

- electrical conductivity, means are average of three replicates; LSD= least significance difference, the means followed by same letter did not differ significantly by DMRT

Table 4 Soil microbial properties of Gual Pahari site analyzed after amendments at wheat harvest

		Microbial parameters		*Mycorrhizal parameters*	
		Total microbial count	*Dehydrogenases*	*Infectious propagules*	*Percent root length*
Treatment		*(cfu/g)*	*(µg/g/24 hrs)*	*(number/10 g soil)*	*colonized by AM*
F1	Inoculated	1 88 x 10^4 c	9.43 b	4.31 b	13.11 c
	Uninoculated	1.93 x 10^4 bc	7.16 b	0.77 d	4.21 e
F2	Inoculated	2.03 x 10^4 bc	10.03 b	4.44 b	15 32 b
	Uninoculated	2.07 x 10^4 bc	9.4 b	1.16 cd	5.55 e
F3	Inoculated	2.44 x 10^4 abc	9.03 b	6.81 a	17.44 a
	Uninoculated	2 48 x 10^4 ab	14.4 a	1 43 c	8.33 d
F4	Inoculated	2.77 x 10^4 a	7.96 b	4.5 b	13.43 bc
	Uninoculated	2.80 x 10^4 a	7 4 b	0.77 d	4.1 e
LSD (0.05)		5.16 x 10^3	2.69	0.53	1 92

Means are average of three replicates; LSD= least significance difference; the means followed by same letter did not differ significantly by DMRT

Table 5 Soil microbial properties of Badshahpur site analyzed after amendments at wheat harvest

		Microbial parameters		*Mycorrhizal parameters*	
		Total microbial count	*Dehydrogenases*	*Infectious Propagules*	*Percent root length*
Treatment		*(cfu/g)*	*(µg/g/24 hrs)*	*(number/10 g soil)*	*colonized by AM*
F1	Inoculated	3.5 x 10^4c	43.5 c	4.84 bc	9.66 c
	Uninoculated	3.46 x 10^4 c	49.6 b	0.24 d	3.66 e
F2	Inoculated	4.22 x 10^4 b	54.2 b	5.18 b	10.77 bc
	Uninoculated	4.17 x 10^4 b	36.9 d	0.21 d	3.55 e
F3	Inoculated	4.41 x 10^4 b	52.5 b	8.65 a	14.92 a
	Uninoculated	4.34 x 10^4 b	59.9 a	0.39 d	5.66 d
F4	Inoculated	4.75 x 10^4 a	30.9 e	3.84 c	11 66 b
	Uninoculated	4.41 x 10^4 b	41.2 cd	0.22 d	3.53 e
LSD (0.05)		2.83 x 10^3	5.32	1.21	1.51

Means are average of three replicates; LSD= least significance difference; the means followed by same letter did not differ significantly by DMRT

Table 6 Effect of fertilizer/manure on growth of wheat inoculated with mycorrhizae grown at Gual Pahari

Treatment		Agronomic characters					
		Grain yield (q/ha)	Weight of 1000 seeds (g)	Straw yield (q/ha)	No of tillers /plant	Plant P (%)	Plant N (%)
F1	Inoculated	26 52 bc	42.22 bcd	34.63 bc	3 47 c	0.026 a	0.411 b
	Uninoculated	24.99 cd	39.35 de	34.8 bc	3 2 c	0.017 c	0.241 g
F2	Inoculated	25.87 bcd	43.97 b	33.76 c	3.0 cd	0.013 d	0.367 c
	Uninoculated	23.3 d	38.69 e	33.77 c	2.67 d	0.005 e	0 332 d
F3	Inoculated	29.62 a	48.93 a	36.86 ab	5.0 a	0.023 b	0 875 a
	Uninoculated	26 59 bc	44 33 b	38.63 a	4.0 b	0.021 b	0.265 f
F4	Inoculated	28.43 ab	43.29 bc	37.07 ab	5.0 a	0.022 b	0.411 b
	Uninoculated	27 47 abc	40.26 cde	38.93 a	4 53 a	0.012 d	0.319 e
LSD (0 05)		2.55	3 1	3.23	0.45	0.003	0 014

Means are average of three replicates; LSD= least significance difference; the means followed by same letter did not differ significantly by DMRT

Table 7 Effect of fertilizer/manure on growth of wheat inoculated with mycorrhizae grown at Badshahpur

Treatment		Agronomic characters					
		Grain yield (q/ha)	Weight of 1000 seeds (g)	Straw yield (q/ha)	No of tillers /plant	Plant P (%)	Plant N (%)
F1	Inoculated	25.16 b	44 66 b	34.66 cde	3.53 d	0 012 b	0 306 f
	Uninoculated	22 17 c	40 62 d	30.84 ef	3.06 e	0.011 bc	0.587 a
F2	Inoculated	23.34 bc	42.74 c	32 26 def	3.17 de	0 024 a	0 292 g
	Uninoculated	21.8 c	42 54 c	30.37 f	2.77 e	0 009 c	0 262 h
F3	Inoculated	28 64 a	47 55 a	39.92 a	5 06 a	0.023 a	0.544 b
	Uninoculated	25.48 b	43 16 bc	35 42 bcd	4 06 c	0 022 a	0 340 e
F4	Inoculated	29 16 a	46 25 a	39 42 ab	5.03 a	0 009 c	0 433 c
	Uninoculated	28 48 a	40 91 d	38.32 abc	4.57 b	0.006 d	0 409 d
LSD (0.05)		2 80	1 49	3 96	0 41	0 002	0 005

Means are average of three replicates; LSD= least significance difference, the means followed by same letter did not differ significantly by DMRT

Table 8 Girth at breast height (GBH) and height in poplar planted at both the sites under integrated nutrient management trial

		Gual Pahari site				Badshahpur site			
		At zero time		At 8 months		At zero time		At 8 months	
Treatment		GBH (cm)	Height (m)	GBH (cm)	Height (m)	GBH (cm)	Height (m)	GBH (cm)	Height (m)
F1	Inoculated	5.26a	2.93a	17.3a	5.43a	5.6a	3.17a	17.76ab	5 43a
	Uninoculated	5.36a	3.03a	17 6a	5.52a	5.36a	2.81a	16.46b	5 1a
F2	Inoculated	5.52a	3.19a	17.9a	5.51a	5.37a	2 93a	17.03ab	5 17a
	Uninoculated	5.63a	2.96a	17 9a	5 63a	5 60a	2.97a	17 27ab	5.37a
F3	Inoculated	5.60a	2.93a	15.93a	5 60a	5.37a	3.33a	18.36a	5 60a
	Uninoculated	5 59a	2 92a	17.4a	5.59a	5 67a	3.10a	17.93a	5.30a
F4	Inoculated	5 37a	3 03a	17.93a	5.37a	5.43a	3 03a	17 90a	5.40a
	Uninoculated	5.28a	2.94a	15.93a	5.28a	5.40a	3.10a	17.4ab	5 47a
LSD(0.05)		0 73	0.37	2.56	0.73	0.47	0.56	1.19	0.58

Means are average of three replicates, LSD: least significance difference, the means followed by same letter did not differ significantly by DMRT

Table 9a Soil chemical characterictics at zero time of TERI's experimental site at Gual Pahari (analysed at the time of laying the mung bean trial)

		Macronutrients and chemical parameters						Micronutrients			
			EC*		Olsen P	K	O.C	Zn	Mn	Fe	Cu
Treatment		pH	(dS/m)	N %	(ppm)	(ppm)	(%)	(ppm)	(ppm)	(ppm)	(ppm)
F1	Inoculated	7.29 a	0.343 a	0.165 c	6 54 bc	87.3 f	0.33 d	27.9 b	234.9 b	8813.8 b	BDL
	Uninoculated	7.51 a	0.336 a	0.260 b	6.28 c	127.3 a	0.70 a	45 a	269.2 a	9932.1 a	BDL
F2	Inoculated	7.3 a	0.223 a	0.294 b	7.09 bc	103.6 c	0.35 d	21.8 cd	153.6 c	6101.5 e	BDL
	Uninoculated	7.67 a	0.206 a	0.276 b	7.68 bc	100.3 c	0.51 b	22.3 cd	235.7 b	7824.8 c	BDL
F3	Inoculated	7.48 a	0.200 a	0.255 b	6.84 bc	83 f	0.43 c	18.7 d	123.6 de	5974.1 f	BDL
	Uninoculated	7.51 a	0.250 a	0.275 b	11.52 a	97.3 cd	0.43 c	21.1 cd	160.7 c	6232.6 d	BDL
F4	Inoculated	7.28 a	0.266 a	0.340 ab	8.60 abc	93.6 de	0.34 d	29.8 b	114.6 e	4007.4 h	BDL
	Uninoculated	7.41 a	0.240 a	0.394 a	9.62 ab	116.6 b	0.66 a	23.9 c	126 4 d	5352 g	BDL
LSD (0.05)		0.399	0.171	0.085	2.97	6 73	0.062	3.32	11.13	7.84	-

electrical conductivity ;Means are average of three replicates; LSD= least significance difference; the means followed by same letter did not differ significantly by DMRT

Table 9b Soil chemical characterictics at zero time of farmer's field at Badshahpur (analyzed at the time of laying the mung bean trial)

Treatment		Macronutrients and chemical parameters						Micronutrients			
		pH	EC* (dS/m)	N %	Olsen P (ppm)	K (ppm)	OC (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
F1	Inoculated	7.81 a	0 240 ab	0.244 ab	10.56 b	93 6 c	0 80 bc	19.2 c	221.3 b	7609.3 c	BDL
	Uninoculated	7.28 cd	0.220 d	0.268 ab	14.27 a	97.6 c	1.03 a	23 8 ab	239 1 a	8709.5 a	BDL
F2	Inoculated	7.43 bcd	0 286 c	0 227 b	6.76 c	126.3 b	0.34 d	20.8 c	206 8 c	7341 d	BDL
	Uninoculated	7.22 d	0.260 cd	0.257 ab	8.92 bc	148 a	0.95 ab	23.9 ab	224 4 b	7893.9 b	BDL
F3	Inoculated	7.64 ab	0.453 a	0.209 b	7.44 c	126 b	0.72 c	20.4 c	117.1 d	6651.4 f	BDL
	Uninoculated	7.57 abc	0.236 cd	0.225 b	8.76 bc	157.6 a	0.95 ab	23.9 ab	126 2 d	6840.6 e	BDL
F4	Inoculated	7.35 bcd	0.350 b	0.228 b	14.5 a	125.3 b	0.81 bc	22.7 b	95.9 f	4420.9 h	BDL
	Uninoculated	7.5 abcd	0.226 cd	0.307 a	11.02 b	131.3 b	1.1 a	24.9 a	106.1 e	5003.3 g	BDL
LSD (0.05)		0.31	0 05	0.06	2.53	10.75	0.16	1.91	9.9	11.39	-

* electrical conductivity, means are average of three replicates

LSD= least significance difference; the means followed by same letter did not differ significantly by DMRT

Table 9c Soil chemical characterictics at zero time of TERI's experimental site at Gwal Pahari (analysed at the time of laying of mung bean trial)

Treatment		Microbiological parameters		Mycorrhizal
		Total culturable microbial count (cfu/g)	Dehydrogenases (µg/g/24 hrs)	Infectious Propagules (nos./10 g soil)
F1	Inoculated	1.88×10^4 c	9.43 b	4 31 b
	Uninoculated	1.93×10^4 bc	7.16 b	0.77 d
F2	Inoculated	2.03×10^4 bc	10.03 b	4.44 b
	Uninoculated	2.07×10^4 bc	9.4 b	1.16 cd
F3	Inoculated	2.44×10^4 abc	9.03 b	6 81 a
	Uninoculated	2.48×10^4 ab	14.4 a	1.43 c
F4	Inoculated	2.77×10^4 a	7.96 b	4 5 b
	Uninoculated	2.80×10^4 a	7.4 b	0.77 d
LSD (0.05)		5.16×10^3	2.69	0.53

* electrical conductivity; means are average of three replicates; LSD= least significance difference, the means followed by same letter did not differ significantly by DMRT

Table 9d Soil chemical characterictics of farmer's field at Badshahpur site at zero time (analyzed at the time of laying of mung bean trial)

Treatment		Microbiological parameters: Total culturable microbial Count (cfu/g)	Microbiological parameters: Dehydrogenases (µg/g/24 hrs)	Mycorrhizal: Infectious Propagules (numbers/10 g soil)
F1	Inoculated	3.5×10^4 c	43.5 c	4.84 bc
	Uninoculated	3.46×10^4 c	49 6 b	0.24 d
F2	Inoculated	4.22×10^4 b	54.2 b	5.18 b
	Uninoculated	4.17×10^4 b	36.9 d	0.21 d
F3	Inoculated	4.41×10^4 b	52.5 b	8 65 a
	Uninoculated	4.34×10^4 b	59.9 a	0.39 d
F4	Inoculated	4.75×10^4 a	30.9 e	3 84 c
	Uninoculated	4.41×10^4 b	41.2 cd	0 22 d
LSD (0.05)		2.83×10^3	5.32	1.21

*electrical conductivity; means are average of three replicates; LSD= least significance difference; the means followed by same letter did not differ significantly by DMRT

Table 10 Effect of fertilizer/manure on growth of mung bean inoculated with mycorrhizae and rhizobium grown at Gual Pahari

		Agronomic characters					
Treatment		Grain yield (q/acre)	Weight of 100 seeds (g)	Number of pods	Plant height (cm)	Plant P (%)	Nodule N (%)
F1	Uninoculated	2 62	3 82		69.16	0.02	0 41
	AM	3.36	3.76	45.63	71.10	0.032	0.48
	Rhizobium	3.95	3 95	50 10	71.76	0.036	0.52
	AM+Rhizobium	4.41	4.05	53.83	72.77	0.047	0.53
F2	Uninoculated	3.82	4.06	44.73	69.43	0 039	0 43
	AM	4.17	3.99	45.10	71.67	0.053	0.50
	Rhizobium	4.59	3.67	45.06	72.23	0.05	0 59
	AM+Rhizobium	4.60	3 67	48.36	67.03	0.047	0.65
F3	Uninoculated	4 61	4.24	64.37	74.43	0.05	0.51
	AM	5.10	3.93	46.43	73.60	0.065	0.51
	Rhizobium	5.25	4.3	50.07	73.16	0.050	0.65
	AM+Rhizobium	5.55	4.04	50.82	74.47	0.069	0.62
F4	Uninoculated	4 7	4.13	60 07	71.47	0.061	0.63
	AM	5.39	4.14	46.60	76.96	0.042	0.51
	Rhizobium	5.3	4.04	54.23	73.87	0.063	0.65
	AM+Rhizobium	5.8	4 17	53 83	72.47	0.074	0.59
LSD (0.05)		0.39	0.41	11.02	6.83	0 011	0.06

** total N includes the shoot N+ N in nodules; means are average of three replicates

LSD= least significance difference; the means followed by same letter did not differ significantly by DMRT

Table 11 Effect of fertilizer/manure on growth of mung bean inoculated with mycorrhizae and rhizobium grown at farmer's field at Badshahpur

		Agronomic characters					
Treatment		Grain yield (q/acre)	Weight of 100 seeds (g)	Number of pods/plant	Plant height (cm)	Plant P (%)	Nodule N (%)
F1	Uninoculated	2.06	3.53	46 00	66.13	0.028	0 35
	AM	2.66	3.81	50.16	69.1	0 036	0 42
	Rhizobium	2.94	3.81	45.1	70.56	0.046	0 46
	AM+Rhizobium	3.61	3 87	56.06	71.1	0 057	0 47
F2	Uninoculated	3 09	3 89	40.26	66.43	0.04	0 40
	AM	3.57	3.54	40.33	73.33	0.06	0.43
	Rhizobium	3.84	3.56	39.6	67.63	0 057	0.53
	AM+Rhizobium	3 94	3.84	43.46	69.96	0.061	0 60
F3	Uninoculated	4.14	3.89	56.6	66.73	0.061	0.47
	AM	4.67	3.89	41.6	67.96	0.074	0 57
	Rhizobium	4.58	4.01	45.26	68.23	0.063	0.59
	AM+Rhizobium	5.37	4.05	42.13	71.33	0 076	0.57
F4	Uninoculated	5.13	3.91	55.36	68.26	0.062	0.42
	AM	5.38	3.91	44.96	71.86	0.065	0.54
	Rhizobium	5 32	3.84	49.16	68.0	0.071	0.55
	AM+Rhizobium	5.42	3.56	48.76	69.16	0.08	0.54
LSD (0.05)		0.28	0 20	10.06	8.44	0.013	0.05

** total N includes the shoot N+ N in nodules; means are average of three replicates

LSD= least significance difference, the means followed by same letter did not differ significantly by DMRT

Table 12 Effect of fertilizer/manure integrated with indigenous mycorrhiza and rhizobium on soil biochemical characteristics analyzed at mung bean grown at TERI's experimental site at Gual Pahari

		Macronutrients and chemical parameters				Microbiological parameters	
Treatment		pH	EC* (dS/m)	Olsen P (ppm)	OC(%))	% AM colonization	Soil dehydrogenases (µg/g/24 hrs)
F1	Uninoculated	7.64	0.41	10.16	0.35	6.14	9.94
	AM	7.44	0.45	9.73	0.34	22.38	10.28
	Rhizobium	7.53	0.40	10.41	0.38	5.88	12.21
	AM+Rhizobium	7.31	0.40	11.46	0 30	24.24	10.88
F2	Uninoculated	7.57	0.41	11 56	0.46	6.18	11.84
	AM	7 54	0.42	10 8	0 70	24 66	12 21
	Rhizobium	7.33	0 45	10.5	0.53	22.46	13.26
	AM+Rhizobium	7.37	0.44	10 57	0.60	27.03	11.68
F3	Uninoculated	7.29	0.49	11.37	0.64	6 99	9 84
	AM	7.25	0.46	10.36	0.51	30.99	14.69
	Rhizobium	7.32	0.41	11.13	0.52	28.66	12 98
	AM+Rhizobium	7.07	0.45	13.03	0.69	32.66	14.92
F4	Uninoculated	7.40	0.47	12.8	0.51	6.01	7.98
	AM	7.41	0.45	9.4	0 49	26.48	11 66
	Rhizobium	7.40	0.41	13 16	0.62	26.30	14.68
	AM+Rhizobium	7.42	0.43	10.3	0.77	27.06	14 38
LSD (0.05)		0.13	0.06	1.6	0.22	-	-

*electrical conductivity, means are average of three replicates

LSD= least significance difference, the means followed by same letter did not differ significantly by DMRT

Table 13 Effect of fertilizer/manure integrated with indigenous mycorrhiza and rhizobium on soil biochemical characteristics analysed at mung bean grown at farmer's field at Badshahpur

		Macronutrients and chemical parameters				*Microbiological parameters*	
			*EC**	*Olsen P*		*% AM*	*Soil dehydrogenases*
Treatment		*pH*	*(dS/m)*	*(ppm)*	*OC(%)*	*colonization*	*(µg/g/24 hrs)*
F1	Uninoculated	7.8	0.18	9.9	0.36	4.48	12.68
	AM	7 6	0 15	9.13	0 36	20.34	20 42
	Rhizobium	7.51	0.16	9.76	0.41	3.88	23.27
	AM+Rhizobium	7.57	0.26	10 13	0.29	20 44	10 18
F2	Uninoculated	7 65	0.24	10 63	0.58	5.66	22 66
	AM	7.70	0.34	9.53	0.83	20.99	24.32
	Rhizobium	7.48	0.23	9 6	0.38	18.66	18 96
	AM+Rhizobium	7.55	0.32	9.02	0.71	26.48	20.94
F3	Uninoculated	7.68	0.27	12.20	0.79	5.18	14.63
	AM	7.67	0.24	9.83	0.56	24.68	20.80
	Rhizobium	7.60	0.25	11.06	0.51	20.34	22.08
	AM+Rhizobium	7.51	0.24	11.83	0.50	28.84	28.36
F4	Uninoculated	7.56	0.30	13.1	0.52	3.86	12.87
	AM	7.89	0.40	9.17	0.47	22.82	18.53
	Rhizobium	7.68	0.26	13.2	0.72	18.01	18.06
	AM+Rhizobium	7.34	0.30	9.6	0.56	20.86	24.76
	LSD (0.05)	0.13	0.03	0.04	0.19	-	-

* electrical conductivity;means are average of three replicates

LSD= least significance difference; the means followed by same letter did not differ significantly by DMRT

Table 14 Percent increment in soil dehydrogenaes and total culturable count over initial time influenced due to inoculation of AM fungi and other biofertilizers at various doses of inorganic fertilizer on wheat (second rotation)

Inoculations		Fertilizer dose (NPK Kg/ha)							
		120.60:40[Z]		120:30:40[Z]		120:60:40[Y]		240.120: 80[Z]	
Previous crop inoculations	Current crop (wheat) inoculations	Dehydrogenases activity (µg/g/24hrs)	Total culturable microbial count (cfu/g soil)	Dehydrogenases activity (µg/g/24hrs)	Total culturable microbial count (cfu/g soil)	Dehydrogenases activity (µg/g/24hrs)	Total culturable microbial count (cfu/g soil)	Dehydrogenases activity (µg/g/24hrs)	Total culturable microbial count (cfu/g soil)
AMF	AMF	143 58	129 44	112 83	67 22	230.74	132 22	118 80	278 33
	AZ01	140.59	153.33	91.34	131.11	261.79	188.33	181.19	228.89
	AZ02	115 82	101.10	142.80	108.89	170 74	133 89	183.19	241.11
	PSBs	151.94	130.0	117.91	111.67	200.89	170.0	142 08	226.67
AMF+Rhizobium	AMF	82.08	118.89	82.98	162.78	148 65	117.78	320.29	242.78
	AZ01	112.53	191.10	151.04	123.89	181.49	122.78	261.49	225.56
	AZ02	170.14	183.88	121.49	115.0	140.29	126.11	289.55	239.44
	PSBs	219.70	182.22	122.68	120.0	172.53	128.89	240.44	176.66
Rhizobium	Rhizobium	62.38	242.77	91.34	174 44	93.13	107.77	295.82	120.0
	AZ01	82.08	246.66	152.83	179.44	112.83	114.44	231.04	126.11
	AZ02	110.44	170.0	119.10	238.89	202 38	61.66	208 65	118.89
	PSBs	118.50	222.77	151.94	230.0	181.19	108.89	229.85	178.33
Uninoculated	Uninoculated	52 23	107.77	32 53	120.0	52.53	67 22	142 08	62.22
	AZ01	56.11	10 0	83.28	70.56	62.38	52.22	182.68	120.0
	AZ02	83.88	22.77	112.83	64 44	83.28	60.55	116.71	127.22
	PSBs	88 05	1 32	148 35	73 89	80 59	71 67	140 29	128 33

Z = FYM was applied@ 8 tonnes/acre, Y= FYM was applied @ 16 tonnes/acre

Table 15 Percent increment in soil macronutrients over initial time influenced by inoculation of AM fungi and other biofertilizers at various doses of inorganic fertilizers on wheat (second rotation)

Inoculation		Fertilizer dose (NPK Kg/ha)											
	Current crop	120 60·50[Z]			120 30:50[Z]			120·60:50[Y]			240·120 100[Z]		
Previous crop	(wheat)	N			N			N			N		
inoculations	Inoculations	(%)	P_2O_5	K_2O	(%)	P_2O_5	K_2O	(%)	P_2O_5	K_2O	(%)	P_2O_5	K_2O
AMF	AMF	88.89	266.40	16.28	77.78	260 3	12.6	100.0	204.49	26.76	108.89	307.4	31 42
	AZ01	122.22	253 17	14.84	133.33	248.67	7.30	148.89	262.69	31 82	183 33	296.56	34 34
	AZ02	77.78	207.40	10.15	77.77	229.36	6.90	82 22	280.42	17 33	112 22	296 54	23 83
	PSBs	122.20	270.37	20.61	144.44	279.89	12.67	192.22	267 19	25 31	144 44	245.76	33 98
AMF+Rhizobium	AMF	155.55	241.26	18.41	155.55	229.62	14.08	222.22	274.34	17.73	182.22	273.01	26.76
	AZ01	166.67	173.80	23.67	200.0	247.61	15.56	211.11	259 25	16.25	180.0	232 80	32 18
	AZ02	137.77	207.14	17.36	134.44	263.49	8.69	166.67	244.44	15.16	166.67	228 04	24.59
	PSBs	162.22	229.10	24.59	163.33	294.18	16.65	155.55	332.27	19.50	198.89	228.83	33 62
Rhizobium	Rhizobium	31.11	158.99	0 032	18.88	143.10	1.12	44.44	225.61	19 53	48.89	223.54	22.42
	AZ01	16.67	206 61	8.69	7.78	236.50	4.73	51.11	230.15	20.26	57.78	280.95	19.53
	AZ02	8.89	191.53	7.61	18.88	231.48	6 53	54.44	261 37	15.92	68 89	241.0	18 09
	PSBs	72.22	237 03	10.14	62 22	280.15	8 34	82.22	387.30	23.51	117.78	281.75	31.09
Uninoculated	Uninoculate	-22.22	127.77	-8.26	7.78	107 41	-4.65	8.88	222.27	12.67	13.33	205.82	20 98
	AZ01	1.11	173.01	1.47	26.66	169.57	6.17	31.11	267.98	24.91	37.77	319 57	25.32
	AZ02	-3.33	171 42	0.03	24.44	160.05	2.19	44.44	336.50	16.65	53.33	329.36	22.43
	PSBs	26.66	152.11	7.98	15.55	190 47	11.56	44.45	264.28	27.84	42.22	279.36	31.09

Z = FYM was applied @ 8 tonnes/acre; Y= FYM was applied @ 16 tonnes/acre

Table 16 Effect of cropping sequence and inoculations of various biofertilizers under integrated nutrient management practices on macronutrients in soil analyzed at harvest (Fertility dose I: 120 N; 50 P; 40 K applied levels of inorganic fertilizers*) in an alfisol at Gual Pahari

Fallow-wheat: crop wheat				Wheat-mungbean . crop mungbean				Mungbean-wheat . crop wheat			
	Macronutrients				Macronutrients				Macronutrients		
Inoculation	N(%)	P_2O_5 (ppm)	K_2O (ppm)	Inoculation	N(%)	P_2O_5 (ppm)	K_2O (ppm)	Inoculation	N(%)	P_2O_5 (ppm)	K_2O (ppm)
								AMF	0.17	13.85	107.33
				AMF	0.306	9.73	126.4	AZO1	0.20	13.35	106.0
								AZO2	0.16	11.62	101.67
AMF	0.165	6.54	87.3					PSBs	0.20	14.0	111.33
								AMF+Rhizobium	0 23	12.9	109.33
				AMF+Rhizobium	0.316	11.46	129.6	AZO1	0.24	10.35	113.67
								AZO2	0.21	11.61	108 33
								PSBs	0.24	12.4	115.0
								Rhizobium	0.12	9.79	92.33
				Rhizobium	0.31	10.41	124.10	AZO1	0 10	11.60	100.3
								AZO2	0.098	11.02	99.33
Uninoculated	0.26	6.28	127.3					PSBs	0.15	12.7	101 66
								Uninoculated	0.073	8.61	84.67
				Uninoculated	0.28	10.16	118.6	AZO1	0.091	10.32	93.66
								AZO2	0 087	10.26	92.33
								PSBs	0.114	9.53	99.67

*FYM was applied @ 8 tonnes/ha

Table 17 Effect of cropping sequence and inoculation of various biofertilizers under integrated nutrient management practices on macronutrients in soil analyzed at harvest (Fertility dose II : 120 N; 25 P; 40 K applied levels of inorganic fertilizer*) in an alfisol (location: Gual Pahari)

Fallow-wheat: crop wheat				Wheat-mungbean : crop mungbean				Mungbean- wheat crop wheat			
	Macronutrients				Macronutrients				Macronutrients		
Inoculation	N (%)	P_2O_5 (ppm)	K_2O (ppm)	Inoculation	N (%)	P_2O_5 (ppm)	K_2O (ppm)	Inoculation	N (%)	P_2O_5 (ppm)	K_2O (ppm)
								AMF	0.16	13.62	104.0
				AMF	0 316	10.8	119 4	AZO1	0.21	13.18	99.33
								AZO2	0.16	12 45	98.67
AMF	0.29	7.09	103.60					PSBs	0.22	14.36	104 0
								AMF+Rhizobium	0 23	12.46	105 3
				AMF+Rhizobium	0.334	10.57	122.4	AZO1	0 27	13 14	106 67
								AZO2	0.21	13.7	100.3
								PSBs	0.237	14.9	107 67
								Rhizobium	0.10	9 19	93.33
				Rhizobium	0.346	10.50	116.3	AZO1	0.097	12 72	96.67
								AZO2	0.107	12.53	98 33
								PSBs	0.146	14.37	100 0
Uninoculated	0.27	7.68	100.3					Uninoculated	0.097	7.84	88.0
				Uninoculated	0.312	11.5	106.4	AZO1	0.114	10.19	98.0
								AZO2	0 112	9.83	94.33
								PSBs	0.10	10.98	103.0

*FYM was applied @ 8 tonnes/acre

Table18 Effect of cropping sequence and inoculation of various biofertilizers under integrated nutrient management practices on micronutrients in soil analyzed at harvest (Fertility dose III: 120 N; 50 P; 40 K applied levels of inorganic fertilizer*) in an alfisol (location: Gual pahari)

Fallow-wheat: crop wheat				Wheat-mungbean · crop mungbean				Mungbean- wheat . crop wheat			
	Macro -nutrients				Macronutrients				Micronutrients		
Inoculations	N (%)	P_2O_5 (ppm)	K_2O (ppm)	Inoculations	N (%)	P_2O_5 (ppm)	K_2O (ppm)	Inoculations	N (%)	P_2O_5 (ppm)	K_2O (ppm)
AMF	0 25	6.84	83.0	AMF	0.364	10 36	116.2	AMF	0.18	11 51	117.0
								AZO1	0.22	13.71	121.67
								AZO2	0.16	14 38	108.2
								PSBs	0.26	13.8	115.67
				AMF+Rhizobium	0.381	13.03	134 6	AMF+Rhizobium	0.29	14.15	108.67
								AZO1	0.28	13.58	107.33
								AZO2	0.24	13.02	106.33
								PSBs	0.23	16 34	110.33
Uninoculated	0.27	11.52	97.3	Rhizobium	0.364	11.13	108.6	Rhizobium	0.13	12.31	110 3
								AZO1	0.136	12 5	111 0
								AZO2	0.14	13.66	107 0
								PSBs	0.17	18 42	114.0
				Uninoculated	0.36	11.37	101.4	Uninoculated	0.098	12.20	104.0
								AZO1	0.118	13.91	115.33
								AZO2	0.138	16.5	107.67
								PSBs	0.133	13.77	118.0

*FYM was applied @ 16 tonnes/acre

Table19 Effect of cropping sequence and inoculation of various biofertilizers under integrated nutrient management practices on macronutrients in soil analyzed at harvest (Fertility dose IV: 240 N; 100 P; 80 K applied levels of inorganic fertilizer*) in an alfisol (location. Gual Pahari)

Fallow-wheat crop wheat				*Wheat-mungbean · crop mungbean*				*Mungbean- wheat crop wheat*			
	Macronutrients				*Macronutrients*				*Macronutrients*		
Inoculation	*N (%)*	*P_2O_5 (ppm)*	*K_2O (ppm)*	Inoculation	*N (%)*	*P_2O_5 (ppm)*	*K_2O (ppm)*	Inoculation	*N (%)*	*P_2O_5 (ppm)*	*K_2O (ppm)*
								AMF	0 19	15.40	121.33
				AMF	0.38	9 73	120.2	AZO1	0.25	14.99	124 0
								AZO2	0.19	14.99	114.33
AMF	0.34	8.60	93.60					PSBs	0.22	13.07	123.67
								AMF+Rhizobium	0 25	14 10	117.0
				AMF+Rhizobium	0.383	11.46	118.4 0	AZO1	0 25	12.58	122.0
								AZO2	0.24	12.40	115.0
								PSBs	0.27	12.43	123.33
								Rhizobium	0.13	12.23	113 0
				Rhizobium	0.376	10.41	117.7	AZO1	0.14	14 40	110.33
								AZO2	0.15	12.90	109.0
Uninoculated	0.39	9.62	106.6					PSBs	0.17	14.43	121.0
								Uninoculated	0.10	11.56	111 67
				Uninoculated	0.38	10 16	112.2 0	AZO1	0.12	15.86	115.67
								AZO2	0.138	16.23	113 0
								PSBs	0 13	14.34	121 0

*FYM was applied @ 8 tonnes/acre

Table 20 Effect of cropping sequence and inoculation of various biofertilizers under integrated nutrient management practices on soil dehydrogenases activity and total microbial culturable count at harvest (Fertility dose I: 120 N; 50 P; 40 K applied levels of inorganic fertilizer) * in an alfisol

	Fallow-wheat. crop wheat			*Wheat-mungbean : crop mungbean*			*Mungbean- wheat : crop wheat*	
	Microbial activity			*Microbial activity*			*Microbial activity*	
Inoculation	*Soil dehydrogenases (μg/g 24hrs)*	*Total microbial culturable count (cfu g/soil)*	Inoculation	*Soil dehydrogenases (μg/g 24hrs)*	*Total microbial culturable count (cfu g/soil)*	Inoculation	*Soil dehydrogenases (μg/g 24hrs)*	*Total microbia culturable cou (cfu g/soil)*
AMF	9.43	1.8×10^4	AMF	10.28	—	AMF	16.32	4.13×10^4
						AZO1	16 12	$4\ 56 \times 10^4$
						AZO2	46.46	3.62×10^4
						PSBs	16.88	4.14×10^4
			AMF+Rhizobium	10.88	—	AMF+Rhizobium	12.20	3.94×10^4
						AZO1	14 24	5.24×10^4
						AZO2	18.10	$5\ 11 \times 10^4$
						PSBs	21.42	5.08×10^4
Uninoculated	7.16	1.9×10^4	Rhizobium	12.21	—	Rhizobium	10.88	6.17×10^4
						AZO1	12 20	6.24×10^4
						AZO2	14 10	4.86×10^4
						PSBs	14.64	5.81×10^4
			Uninoculated	9.94	—	Uninoculated	10 20	$3\ 74 \times 10^4$
						AZO1	10 46	$1\ 98 \times 10^4$
						AZO2	12 32	$2\ 21 \times 10^4$
						PSBs	12 60	4.17×10^4

*FYM was applied @ 8 tonnes/ha

Table 21 Effect of cropping sequence and inoculation of various biofertilizers under integrated nutrient management practices on soil dehydrogenases activity and total microbial culturable count at harvest (Fertility dose II : 120 N; 25 P; 40 K applied levels of inorganic fertilizer) * in an alfisol

	Fallow-wheat crop wheat			*Wheat-mungbean. crop mungbean*			*Mungbean- wheat. crop wheat*	
	Microbial activity			Microbial activity			Microbial activity	
Inoculations	Soil dehydrogenases ($\mu g/g$ 24hrs)	Total microbial culturable count (cfu g/soil)	Inoculations	Soil dehydrogenases ($\mu g/g$ 24hrs)	Total microbial culturable count (cfu g/soil)	Inoculations	Soil dehydrogenases ($\mu g/g$ 24hrs)	Total microbial culturable count (cfu g/soil)
						AMF	14.26	3.01×10^4
						AZO1	12.82	4.16×10^4
			AMF	12.21	—	AZO2	16.22	3.76×10^4
						PSBs	14.60	3.81×10^4
AMF	10.03	2.03×10^4				AMF+Rhizobium	12.28	4.73×10^4
						AZO1	16.82	4.03×10^4
			AMF+Rhizobium	11.68	—	AZO2	14.82	3.87×10^4
						PSBs	14.92	3.96×10^4
						Rhizobium	12.82	4.94×10^4
						AZO1	16.94	5.03×10^4
			Rhizobium	13.26	—	AZO2	14.68	6.10×10^4
						PSBs	16.88	5.94×10^4
Uninoculated	9.4	2.07×10^4				Uninoculated	8.88	3.96×10^4
						AZO1	12.28	3.07×10^4
			Uninoculated	11.84	—	AZO2	14.26	2.96×10^4
						PSBs	16.64	3.13×10^4

*FYM was applied @ 8 tonnes/ha

Table 22 Effect of cropping sequence and inoculation of various biofertilizers under integrated nutrient management practices on soil dehydrogenases activity and total microbial culturable count at harvest (Fertility dose III: 120 N; 50 P; 40 K applied levels of inorganic fertilizer)* in an alfisol at Gual Pahari

Fallow-wheat: crop wheat	Microbial activity		Wheat-mungbean : crop mungbean	Microbial activity		Mungbean- wheat crop wheat	Microbial activity	
Inoculation	Soil dehydrogenases (µg/g 24hrs)	Total microbial culturable count (cfu g/soil)	Inoculation	Soil dehydrogenases (µg/g 24hrs)	Total microbial culturable count (cfu g/soil)	Inoculation	Soil dehydrogenases (µg/g 24hrs)	Total microbial culturable count (cfu g/soil)
						AMF	22.16	4.18×10^4
			AMF	14.69	—	AZO1	24.24	$5\ 19 \times 10^4$
						AZO2	18.14	4.21×10^4
AMF	9.03	2.4×10^4				PSBs	20.16	4.86×10^4
						AMF+Rhizobium	16.66	3.92×10^4
			AMF+Rhizobium	14.92	—	AZO1	18.86	4.01×10^4
						AZO2	16.10	4.07×10^4
						PSBs	18.26	4.12×10^4
						Rhizobium	12.94	3.74×10^4
			Rhizobium	12.98	—	AZO1	14.29	$3\ 86 \times 10^4$
						AZO2	20.26	2.91×10^4
Uninoculated	14.40	2.48×10^4				PSBs	18.84	3.76×10^4
						Uninoculated	10.22	3.01×10^4
			Uninoculated	9.84	—	AZO1	10.88	$2\ 74 \times 10^4$
						AZO2	12.28	$2\ 89 \times 10^4$
						PSBs	12.10	3.09×10^4

*FYM was applied @ 16 tonnes/ha

Table 23 Effect of cropping sequence and inoculations of various biofertilizers under integrated nutrient management practices on soil dehydrogenases activity and total microbial culturabe count at harvest (Fertility dose IV : 240 N; 100 P; 80 K applied levels of inorganic fertilizer)* in an alfisol at Gual Pahari

Fallow-wheat: crop wheat — *Microbial activity*

Inoculation	*Soil dehydrogenases ($\mu g/g$ 24hrs)*	*Total microbial culturable count (cfu g/soil)*
AMF	7.96	2.7×10^4
Uninoculated	7.40	2.8×10^4

Wheat-mungbean. crop mungbean — *Microbial activity*

Inoculation	*Soil dehydrogenases ($\mu g/g$ 24hrs)*	*Total microbial culturable count (cfu g/soil)*
AMF	11.66	—
AMF+Rhizobium	14.38	—
Rhizobium	14.68	—
Uninoculated	7.98	—

Mungbean- wheat. crop wheat — *Microbial activity*

Inoculation	*Soil dehydrogenases ($\mu g/g$ 24hrs)*	*Total microbial culturable count (cfu g/soil)*
AMF	14 66	6.81×10^4
AZO1	18 84	5.92×10^4
AZO2	18 99	6.14×10^4
PSBs	16.22	5.88×10^4
AMF+Rhizobium	28.16	6.17×10^4
AZO1	24.22	5.86×10^4
AZO2	26.10	6.11×10^4
PSBs	22 81	4.98×10^4
Rhizobium	26.52	3.96×10^4
AZO1	22 18	4.07×10^4
AZO2	20.68	3.94×10^4
PSBs	22.10	5.01×10^4
Uninoculated	16.22	2.92×10^4
AZO1	18.94	3.96×10^4
AZO2	14.52	4.09×10^4
PSBs	16 10	4.11×10^4

*FYM was applied @ 8 tonnes/ha

Table 24 Effect of cropping sequence and inoculation of various biofertilizers under integrated nutrient management practices on grain yield and nutrient uptake in plant tissues at harvest (Fertility dose I: 120 N; 50 P; 40 K applied levels of inorganic fertilizers)* in an alfisol at Gual Pahari

	Fallow-wheat: crop wheat				Wheat-mungbean : crop mungbean				Mungbean- wheat : crop wheat		
	Yield and plant uptake				Yield and plant uptake				Yield and plant uptake		
Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)	Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)	Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)
								AMF	32.29	0.14	0.20
				AMF	8 4	0.032	0.48	AZO1	33.46	0.11	0.24
								AZO2	30.86	0.12	0.21
AMF	26.52	0.026	0 41					PSBs	33 04	0 16	0 20
								AMF+Rhizobium	33.46	0.12	0.21
				AMF+Rhizobium	11.02	0.047	0.53	AZO1	34.18	0.11	0.24
								AZO2	31.86	0.11	0.22
								PSBs	34.92	0.15	0.21
								Rhizobium	28.14	0.074	0.19
				Rhizobium	9.87	0.036	0.52	AZO1	30.86	0.10	0.25
								AZO2	29.81	0.098	0.21
Uninoculated	24 99	0.017	0.24					PSBs	30 92	0.11	0.20
								Uninoculated	28.03	0.087	0.09
				Uninoculated	6.55	0.02	0.41	AZO1	28.16	0 088	0.22
								AZO2	27.04	0.089	0.20
								PSBs	30.19	0.12	0.19

*FYM was applied @8 tonnes/ha

Table 25 Effect of cropping sequence and inoculation of various biofertilizers under integrated nutrient management practices on grain yield and nutrient uptake in plant tissues at harvest (Fertility dose II : 120 N; 25 P; 40 K applied levels of inorganic fertilizer)* in an alfisol at Gual Pahari

	Fallow-wheat crop wheat				Wheat-mungbean · crop mungbean				Mungbean- wheat crop wheat		
	Yield and plant uptake				Yield and plant uptake				Yield andpPlant uptake		
Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)	Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)	Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)
								AMF	30.18	0.12	0 19
								AZO1	31.16	0.13	0.23
				AMF	10.42	0.053	0.50	AZO2	28.92	0.11	0.21
								PSBs	31 10	0.13	0 19
AMF	25.87	0 013	0 36					AMF+Rhizobium	31.86	0 10	0 20
								AZO1	32 19	0.11	0 22
				AMF+Rhizobium	11.5	0 047	0.65	AZO2	29.92	0 10	0.20
								PSBs	32.86	0 12	0 19
								Rhizobium	26.08	0.089	0.16
								AZO1	28.93	0.10	0.23
				Rhizobium	11.47	0.05	0.59	AZO2	27 92	0 095	0.22
								PSBs	28 88	0.11	0.15
Uninoculated	23.30	0.005	0.33					Uninoculated	26.68	0.069	0 08
								AZO1	26 62	0.10	0 25
				Uninoculated	9.55	0 039	0.43	AZO2	26.37	0.11	0.25
								PSBs	28 44	0.14	0.25

*FYM was applied @ 8 tonnes/ha

Table 26 Effect of cropping sequence and inoculation of various biofertilizers under integrated nutrient management practices on grain yield and nutrient uptake in plant tissues at harvest (Fertility dose III: 120 N; 50 P; 40 K applied levels of inorganic fertilizer)* in an alfisol at Gual Pahari

Fallow-wheat crop wheat				Wheat-mungbean . crop mungbean				Mungbean- wheat : crop wheat			
	Yield and plant uptake				Yield and plant uptake				Yield and plant uptake		
Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)	Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)	Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)
								AMF	36.86	0.27	0.31
				AMF	12.75	0.065	0 51	AZO1	34 76	0.24	0.43
								AZO2	34.08	0.24	0.41
AMF	29.62	0.023	0.87					PSBs	35.58	0 26	0 30
								AMF+Rhizobium	36 92	0.28	0 32
				AMF+Rhizobium	13.87	0.069	0.62	AZO1	34 88	0 27	0.40
								AZO2	33.96	0 27	0.52
								PSBs	36.98	0.31	0 33
								Rhizobium	32 91	0.20	0 34
				Rhizobium	13.12	0.05	0.65	AZO1	34.89	0 23	0.35
								AZO2	35 24	0 22	0.39
Uninoculated	26.59	0.021	0.26					PSBs	36 11	0.26	0 30
								Uninoculated	29.98	0 21	0.28
				Uninoculated	11.52	0.05	0.51	AZO1	30 22	0.20	0.47
								AZO2	30.01	0.22	0.36
								PSBs	32.10	0.26	0.30

*FYM was applied @16 tonnes/ha

Table 27 Effect of cropping sequence and inoculation of various biofertilizers under integrated nutrient management practices on grain yield and nutrient uptake in plant tissues at harvest (Fertility dose IV: 240 N; 100 P; 80 K applied levels of inorganic fertilizer)* in an alfisol at Gual Pahari

Fallow-wheat. crop wheat				Wheat-mungbean. crop mungbean				Mungbean-wheat: crop wheat			
	Yield and plant uptake				Yield and plant uptake				Yield and plant uptake		
Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)	Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)	Inoculation	Grain yield (q/ha)	Plant P (%)	N (%)
								AMF	36 92	0.21	0.43
				AMF	13.47	0.042	0.51	AZO1	34 61	0 27	0 49
								AZO2	33.82	0 29	0 47
								PSBs	37.08	0.27	0.39
AMF	28.4	0.022	0.411					AMF+Rhizobium	36 96	0 25	0 47
				AMF+Rhizobium	14.50	0.074	0 59	AZO1	34.91	0.26	0 51
								AZO2	32.88	0 27	0 55
								PSBs	37.26	.28	0.44
								Rhizobium	31.98	0 23	0.46
				Rhizobium	13.25	.063	0.65	AZO1	33 74	0.25	0.47
								AZO2	34.10	0.26	0 49
								PSBs	36.27	0 27	0.42
Uninoculated	27.47	0.012	0.31					Uninoculated	31.68	0.22	0.42
				Uninoculated	11.75	0.061	0.63	AZO1	31.16	0.26	0.49
								AZO2	31.42	0.26	0.50
								PSBs	33.66	0 29	0 46

*FYM was applied @ 8 tonnes/ha

Table 28 Interaction effect of fertility levels and biofertilizers on growth and yield of wheat at harvest (mungbean-wheat rotation) location: Gual pahari

Inoculation		Fertilizer a pplied levels (NPK, Kg/ha)											
		120-50-40z			120-25-40z			120-50-40y			240-100-80z		
Previous inoculations	Current inoculations	Grain yield (q/ha)	Straw yield (q/ha)	No. of tillers/ plants	Grain yield (q/ha)	Straw yield (q/ha)	No. of tillers/ plant	Grain yield (q/ha)	Straw yield (q/ha)	No. of tillers	Grain yield (q/ha)	Straw yield (q/ha)	No. of tillers/ plant
AMF	AMF	32 29	38.78	4.28	30.18	36.08	4 01	36.86	43 84	5.12	36.92	42.99	5.07
	AZO1	33.46	39.22	4.36	31.16	36 88	4 21	34.86	42.93	4.92	34.61	40.84	4.82
	AZO2	30 86	36.92	4.16	28.92	34.97	4 03	34.08	40 90	4.01	33.82	40.08	4.10
	PSBs	33 04	40.01	4.52	31.10	36.84	4.29	35.58	42.10	4.52	37.08	43.41	4.64
AMF+ Rhizobium	AMF+Rh	33.46	38.98	4 06	31 86	37 92	3.92	36.92	43.08	4.82	36.96	42.28	5.01
	AZO1	34.18	40.21	4.62	32.19	38.09	4 11	34.88	40.92	4.42	34.91	41.77	4.71
	AZO2	31.86	38 26	4.11	29.92	36 01	3.99	33.96	40 08	4.23	32.88	39 26	4 12
	PSBs	34 92	42 10	4 74	32 86	39 01	4 13	36 98	43 89	5.42	37 26	43 06	5 60
Rhizobium	Rh	28 14	34.88	3.98	26.78	32.42	3.62	31 91	39 01	3.81	31.98	37 42	4.01
	AZO1	30 86	37.23	4.18	28 93	34.90	3 87	34 89	41 66	4.04	33 74	41.08	4.01
	AZO2	29.81	36.84	4 10	27.92	33 86	3.66	35.24	40.88	4.01	34.10	41.22	3.92
	PSBs	30.92	36.89	4 21	28.88	34 92	3.92	36.11	40.97	4.62	36.27	42.76	4.66
Control	Control	28.03	33 52	3 80	26 68	31.72	3 58	29 98	34.92	3.86	31 68	37 04	4 24
	AZO1	28 16	35.78	3.92	26.62	32.60	3.68	30 22	36.90	3.96	31.16	36.96	3.83
	AZO2	27.04	35.71	3.91	26.37	32.89	3 74	30 01	37.08	3 99	31 42	36.99	3.97
	PSBs	30.19	36 89	4.19	28.44	35.03	3.98	32 10	38.84	4.27	33.66	39.14	4 12
LSD (0.05) Fertilizer doses													
LSD (0.05) Inoculations		0 84	0.98	0 072							0.42	0 49	.036
Interaction (inoc x fertility levels)		**	***	***									

Z = FYM was applied @ 8 tonnes/ha, y = FYM applied @16 tonnes/ha

Table 29 Interaction effect of fertility levels and biofertilizers on available nutrients in soil at harvest (mungbean-wheat rotation, crop wheat) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)											
		120-50-40z			120-25-40z			120-50-40y			240-100-80z		
Previous inoculations	Current inoculations	N (%)	P_2O_5 (ppm)	K_2O (ppm)	N (%)	P_2O_5 (ppm)	K_2O (ppm)	N (%)	P_2O_5 (ppm)	K_2O (ppm)	N (%)	P_2O_5 (ppm)	K_2O (ppm)
AMF	AMF	0.17	13 85	107 3	0.16	13.62	104.0	0.18	11.51	117 0	0.188	15.40	121 33
	AZO1	0.20	13.35	106 0	0.21	13.18	99.33	0.224	13.71	121 67	0.255	14.99	124 0
	AZO2	0.16	11.62	101.6	0 16	12.45	98 67	0 164	14 38	108 33	0 191	14.99	114.33
	PSBs	0.20	14.0	111 3	0.22	14.36	104.0	0.263	13.88	115.67	0.222	13.07	123.67
AMF+ Rhizobium	AMF+Rh	0.23	12.9	109.3	0.23	12.46	105.3	0.29	14.15	108.67	0.254	14 10	117.0
	AZO1	0.249	10 35	113.6	0.27	13.14	106.6	0.28	13.58	107.33	0.252	12.58	122.0
	AZO2	0.214	11.61	108.3	0.211	13.74	100.3	0.24	13.02	106.33	0.240	12.40	115.0
	PSBs	0.236	12.44	115.0	0.237	14.9	107.6	0.23	16.34	110.33	0.269	12.43	123.33
Rhizobium	Rh	0.118	9.79	92.33	0 107	9.19	93.33	0.131	12.31	110.33	0.134	12.23	113.0
	AZO1	0.105	11.59	100.3	0.097	12.72	96.67	0.136	12.48	111.0	0.142	14.40	110.33
	AZO2	0.098	11.02	99.33	0.107	12.53	98.33	0.139	13.66	107.0	0.152	12 89	109.0
	PSBs	0.155	12.74	101.6	0.146	14.37	100.0	0.164	18.42	114.0	0.169	14.43	121 0
Control	Control	0.073	8 61	84 67	0.097	7.84	88.0	0.098	12.20	104 0	0.102	11.56	111 67
	AZO1	0.091	10.32	93.66	0.114	10.19	98.0	0.118	13.91	115.33	0.124	15.86	115 67
	AZO2	0.087	10.26	92.33	0.112	9.83	94.33	0.130	16.50	107.67	0.138	16.23	113.0
	PSBs	0.114	9.53	99.67	0.104	10.98	103.0	0.133	13 77	118 0	0 128	14.34	121.0
LSD (0.05) Fertilizer doses											0.008	0.62	2 13
LSD (0.05) Inoculations		0.017	1.24	4 26									
Interaction (inoc. X fertility levels)		NS	***	**									

Z = FYM was applied @ 8 tonnes/ha ; y = FYM applied @16tonnes/ha

Table 30 Interaction effect of fertility levels and biofertilizers on soil chemical characteristics at harvest (mungbean-wheat rotation, crop wheat) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)											
		120-50-40z			120-25-40z			120-50-40y			240-100-80z		
Previous inoculations	Current inoculations	pH	EC (dS/m)	O.C (%)	pH	EC (dS/m)	O.C (%)	PH	EC (dS/m)	O.C (%)	pH	EC (dS/m)	O C (%)
AMF	AMF	7.29	0.3	0.88	6.98	0.40	0.76	6.99	0.34	0.89	7.04	0 32	0.98
	AZO1	7 33	0 36	0 86	7 02	0.36	0.70	7.0	0.30	0.86	7.02	0.31	0.95
	AZO2	7 30	0.34	0 85	7.11	0.41	0.71	7.01	0.34	0 83	7.07	0.32	0.92
	PSBs	7.28	0.32	0.89	7.03	0.34	0.83	6.97	0.35	0.92	7.03	0.32	0 91
AMF+ Rhizobium	AMF+Rh	7.22	0.37	0.88	7.07	0 29	0.79	7 02	0 30	0.84	7 02	0 32	1 01
	AZO1	7.23	0.39	0.90	7 09	0.35	0.79	6 99	0.37	0.90	7.06	0.33	0.91
	AZO2	7.36	0.32	0 83	6 99	0.34	0.76	6 98	0 33	0.89	7 01	0.35	0.89
	PSBs	7.25	0.30	0 93	7 0	0.33	0.80	6.99	0.30	0.96	7.04	0.33	0.95
Rhizobium	Rh	7.33	0.41	0.66	7.23	0.32	0.60	7 03	0 29	0 85	7.06	0.35	0.91
	AZO1	7.27	0.41	0.73	7.13	0.28	0.62	7.01	0 34	0 89	7 03	0 34	0.93
	AZO2	7.34	0 37	0.71	7.10	0.31	0.59	7.03	0.32	0.83	7.05	0.30	0.95
	PSBs	7.32	0.33	0.81	7.17	0 35	0 68	6 99	0.33	0.90	7.06	0.31	0.96
Control	Control	7.23	0.42	0.55	7.06	0.31	0.52	6 93	0 31	0.84	7.0	0.35	0.92
	AZO1	7.37	0.41	0 62	6 99	0.32	0 60	6.96	0.32	0.87	7 05	0.27	0.91
	AZO2	7.12	0.31	0.68	7 06	0 34	0 57	7.01	0 34	0.83	7.13	0.31	0.93
	PSBs	7.24	0.28	0 69	7.10	0.33	0.61	7 07	0 33	0.66	7.09	0.31	0 94
LSD (0.05) Fertilizer doses		0 03	0 024	0 037									
LSD (0.05) Inoculations		0.070	.048	0 075									
Interaction (inocu X fertility levels)		NS	NS	NS									

Z = FYM was applied @ 8 tonnes/ha , y = FYM applied @16tonnes/ha

Table 31 Interaction effect of fertility levels and biofertilizers on nutrient uptake in wheat plants at harvest (mungbean-wheat rotation, crop wheat) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)															
		120-50-40z				120-25-40z				120-50-40y				240-100-80z			
Previous inoculations	Current inoculations	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
	AMF	93.45	27 92	1401 8	10.25	42.88	57.01	1281.8	12.67	50 66	81 71	1439.1	15.43	50 47	93 21	1692.8	6.06
AMF	AZO1	102.76	40.76	2509.5	11.45	65.71	90.40	2404 6	15.38	86.34	98.19	2096.9	16.90	89 45	101.9	2202 2	7.13
	AZO2	124 42	120.4	1683 0	11.32	94.96	100 75	2581.8	15 70	77 06	126 22	2786.4	19.52	70 33	141 3	2491.6	13.47
	PSBs	133.34	78.0	1754 5	14 89	123 07	137.43	2538 7	20 0	92 76	153 13	2309.6	20.67	61.92	119.1	2898.5	9.99
	AMF+Rh	72.56	84.78	1506.7	15.48	47.48	47.68	1053.6	17.30	56.08	79 18	1355 0	15 93	44.37	66.44	1427.4	10 11
AMF+	AZO1	88.28	126.0	1784.1	17.17	54.48	66 67	1135.7	18 61	79 55	103 15	2416 0	18 62	111.1	97 95	1993 9	20.65
Rhizobium	AZO2	135.46	125.8	1876.8	20.98	128.38	91.07	2477.2	21.51	83.29	119.40	2896.3	19.93	64.61	152.3	1913 3	17.67
	PSBs	110.96	168.4	2359.1	19.40	131.90	104.23	2074.6	23.77	113 46	133.14	2632.0	22.35	183.6	132.7	2080 5	23.65
	Rh	29 60	36.0	1109.6	6.40	30 68	28 80	1533.1	11.49	61 53	41.88	1071.9	15.30	51 62	63.83	2056.4	8.18
Rhizobium	AZO1	78.12	40.81	1580.1	17.29	85.56	91.63	1922.1	13.48	98.65	61.39	1585.8	17.70	55 79	101.9	2436.38	12.77
	AZO2	145.67	93.14	1646.8	19.54	101.27	129 37	2385 1	16.54	88.58	86.97	1618.3	20 81	133.01	120.2	2874 86	14.27
	PSBs	146.40	119.2	1750.7	26.86	108.72	149.12	1910.6	26.38	125.25	131.54	2580.5	28.52	65.12	150.4	2932.69	22.98
	Control	37.28	15.26	1564.1	3.20	26.38	29.73	904.8	4.02	39.48	53.43	1089.8	12.01	37.78	56.06	1302.9	4.67
Control	AZO1	48.56	25.94	1983.4	9.17	28.70	67.11	1087.2	9.28	49.51	72.82	1193.8	13.94	56.27	82.74	1556 2	6.92
	AZO2	72.66	61.48	1841.9	16.12	130.70	72.31	2803.7	33.18	63.80	99.60	1497.9	17.52	123.3	161 3	3442.5	9.40
	PSBs	124.99	80.69	2155.2	10.29	182.77	91.67	2908.9	25 09	97.74	147.20	2418.5	28.63	73 83	107 8	2214.89	14.56
LSD (0.05) Fertilizer doses		1.12	2.52	33.72	0 75												
LSD (0.05) Inoculations		2.23	5.04	67.44	1.49												
Interaction (inocu. X fertility levels)		***	***	***	***												

Z = FYM was applied @ 8 tonnes/ha ; y = FYM applied @16 tonnes/ha

Table 32 Interaction effect of fertility levels and biofertilizers on changes in micronutrients in soil at harvest (mungbean-wheat rotation, crop wheat) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)															
		120-50-40z				120-25-40z				120-50-40y				240-100-80z			
Previous inoculations	Current inoculations	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	C (ppm
	AMF	57.77	648.30	22726 1	10.65	61.36	560.37	22981.7	14.87	79.47	734.22	23157.6	10.71	74.34	870 13	23661 4	14.3
AMF	AZO1	63 17	632.61	23309.4	9.93	64.71	572.46	22239.7	11.80	75.32	724.32	22325.6	11.54	75.33	758.58	23138 3	14.3
	AZO2	64.48	611.54	23209.4	11.28	66.62	584.80	21972.5	13.73	77.62	741.29	22193.1	13.12	72 66	804 45	23716.2	14.8
	PSBs	65.06	638.12	22584.7	9.60	72.51	577.16	21971.2	13.50	75.01	763.31	22503.6	12.67	75.15	783.77	22977 3	16.3
	AMF+Rh	57.65	571.22	23328.7	14 19	69 23	584.72	21331.8	9.75	100.62	783.77	22878.8	12.36	77.57	879.84	23646.0	11.6
AMF+ Rhizobium	AZO1	60.52	574.70	23273.0	12.25	67 48	593.45	22378.7	10.18	99.54	758.48	22481.9	11.55	96 21	847.05	23311.2	13.8
	AZO2	65.07	624 66	22468.6	12.74	72.38	584.79	22540.2	10.44	79.59	732.30	23050.9	12 39	84.55	892.54	23575.7	15.4
	PSBs	61 78	626.71	22895.8	13.63	72.19	591.69	22093.3	11.30	104.34	646.52	23276.5	11.86	92.76	757.73	22880 5	18.3
	Rh	50.77	573 33	21657.1	9.56	51.85	533.46	21916.6	7.29	70.37	656.76	22559.1	7.83	76.72	716.65	23853.8	11.9
Rhizobium	AZO1	49.76	582.79	22721.8	12.61	55.59	577.20	22746.3	9.20	71.31	763.41	23136.5	9.75	74.79	737.50	22945.3	13.0
	AZO2	51.78	544.22	22258.8	12.70	54.54	564.02	21380.4	8.77	72.34	698.42	23146.4	10.35	77.28	789.86	23146.4	12.6
	PSBs	54.96	562.38	21108.6	12.79	55.27	566.38	22275.9	10.54	72.26	749.97	23673.5	11.25	74.58	744.65	23335.7	14.0
	Control	35.33	564.90	22080 2	3 33	35.58	566.08	21512.8	4.06	77.76	713.70	22572.8	6.36	75.02	684.40	23490.2	8.8
Control	AZO1	43.16	576.57	24354.7	6.98	42.81	580.12	22683.7	6.24	74.85	724.23	23672.0	8.99	73.39	738.84	22607.8	9.8
	AZO2	44.78	657.82	25509.7	7.52	47.72	557.04	22214.4	6.18	76.37	776.21	23134.2	9.67	85.58	763.47	23569.5	10.9
	PSBs	48.59	578.74	19831.7	8.95	51.52	580.69	22496.5	7 40	76.14	772.08	23587.8	9.98	93.69	784.82	23163.6	10.8
LSD (0.05) Fertilizer doses		2.52	8.65	0.32	127.76												
LSD (0.05) Inoculations		5.03	17.30	0 66	255.53												
Interaction (inocu. X fertility levels)		***	***	***	***												

Z = FYM was applied @ 8 tonnes/ha, y = FYM applied @16 tonnes/ha

Table 33 Interaction effect of fertility levels and biofertilizers on nutrient uptake of wheat at harvest (mungbean-wheat rotation, crop wheat) location: Gual Pahari

Inoculation		*Fertilizer applied levels (NPK/ha)*							
		120-50-40z		120-25-40z		120-50-40y		240-100-80z	
Previous inoculations	Current inoculations	*N uptake (%)*	*Plant P uptake (ppm)*	*N Uptake (%)*	*Plant P uptake %*	*N uptake (%)*	*Plant P uptake %*	*N Uptake (%)*	*Plant P uptake %*
AMF	AMF	0 20	0.14	0.19	0.12	0.31	0.27	0.43	0.21
	AZO1	0.24	0 11	0.23	0 13	0.43	0.24	0 49	0 27
	AZO2	0.21	0.12	0.21	0.11	0.41	0 24	0.47	0.29
	PSBs	0 20	0 16	0.19	0.13	0 30	0.26	0 39	0 27
AMF+ Rhizobium	AMF+Rh	0.21	0.12	0 20	0.10	0.32	0 28	0.47	0.25
	AZO1	0.24	0.11	0.22	0.11	0.40	0 27	0.51	0.26
	AZO2	0.22	0.11	0 20	0 10	0.52	0.27	6 55	0 27
	PSBs	0.21	0.15	0.19	0.12	0.33	0.31	0.44	0.28
Rhizobium	Rh	0.19	0.074	0.16	0.089	0.34	0.20	0.46	0.23
	AZO1	0.25	0.10	0.23	0 10	0.35	0.23	0.47	0.25
	AZO2	0.21	0.098	0.22	0.095	0.39	0.22	0.49	0.26
	PSBs	0.20	0.11	0.15	0.11	0.30	0.26	0.42	0.27
Control	Control	0.09	0.087	0 08	0.069	0.28	0 21	0.42	0 22
	AZO1	0.22	0.088	0.25	0.10	0.47	0.20	0.49	0.26
	AZO2	0.20	0.089	0.25	0 11	0.36	0.22	0.50	0.26
	PSBs	0.19	0.128	0.26	0.14	0.30	0.26	0.46	0 29
LSD (0.05) Fertilizer doses		0.011	0.008						
LSD (0.05) Inoculations		0.024	0 014						
Interaction (inocu. X fertility levels)		***	***						

Z = FYM was applied @ 8 tonnes/ha ; y = FYM applied @16 tonnes/ha

Table 34 Interaction effect of fertility levels and biofertilizers on microbial activity in soil at harvest (mungbean-wheat rotation, crop wheat) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)							
		120-50-40z		120-25-40z		120-50-40y		240-100-80z	
Previous inoculations	Current inoculations	Total culturable micobial count (cfu/g soil)	Soil dehydrogenases activity (µg/g/24hrs)	Total culturable micobial count (cfu/g soil)	Soil dehydrogenases activity (µg/g/24hrs)	Total culturable micobial count (cfu/g soil)	Soil dehydrogenases activity (µg/g/24hrs)	Total culturable micobial count (cfu/g soil)	Soil dehydrogenases activity (µg/g/24hrs)
	AMF	4.13×10^4	16.32	3.01×10^4	14.26	4.18×10^4	22.16	6.81×10^4	14.66
AMF	AZO1	4.56×10^4	16.12	4.16×10^4	12.83	5.19×10^4	24.24	5.92×10^4	18.84
	AZO2	3.62×10^4	46.46	3.76×10^4	16.22	4.21×10^4	18.14	6.14×10^4	18.99
	PSBs	4.14×10^4	16.88	3.81×10^4	14.60	4.86×10^4	20.16	5.88×10^4	16.22
	AMF+Rh	3.94×10^4	12.20	4.73×10^4	12.26	3.92×10^4	16.66	6.17×10^4	28.16
AMF+ Rhizobium	AZO1	5.24×10^4	14.24	4.03×10^4	16.82	4.01×10^4	18.86	5.86×10^4	24.22
	AZO2	5.11×10^4	18.10	3.87×10^4	14.82	4.07×10^4	16.10	6.11×10^4	26.10
	PSBs	5.08×10^4	21.42	3.96×10^4	14.92	4.12×10^4	18.26	4.98×10^4	22.81
	Rh	6.17×10^4	10.88	4.94×10^4	12.82	3.74×10^4	12.94	3.96×10^4	26.52
Rhizobium	AZO1	6.24×10^4	12.20	5.03×10^4	16.94	3.86×10^4	14.26	4.07×10^4	22.18
	AZO2	4.86×10^4	14.10	6.10×10^4	14.68	2.91×10^4	20.26	3.94×10^4	20.68
	PSBs	5.81×10^4	14.64	5.94×10^4	16.88	3.76×10^4	18.84	5.01×10^4	22.10
	Control	3.74×10^4	10.20	3.96×10^4	8.88	3.01×10^4	10.22	2.92×10^4	16.22
Control	AZO1	1.98×10^4	10.46	3.07×10^4	12.28	2.74×10^4	10.88	3.96×10^4	18.94
	AZO2	10.88×10^4	12.32	2.96×10^4	14.26	2.89×10^4	12.28	4.09×10^4	14.52
	PSBs	12.28×10^4	12.60	3.13×10^4	16.64	3.09×10^4	12.10	4.11×10^4	16.10
LSD (0.05) Fertilizer doses		1045.37	12.10						
LSD (0.05) Inoculations		2090.75	0.77						
Interaction (inocu. X fertility)		***	***						

Z = FYM was applied @ 8 tonnes/ha ; y = FYM applied @16 tonnes/ha

Table 35 Economics of wheat as influenced by biofertilizer inoculations at various fertility levels (Crop: wheat, location Gual Pahari)

Fertilizer level	Kharif inoculation	Current inoculation	*Grain yield (q/ha)*	*Additional yield over control[x] (q/ha)*	*Additional returns (Rs/ha)*	*Additional cost of input added over control*	*Additional net returns (Rs/ha)*	ICBR
120-50-40 kg NPK/ha +8 tonnes FYM/acre	AMF	AMF	32.29	4.2	2520	450	2310	1:5.1
		AZO+PSBs	32.45	4.4	2640	350	2290	1:6.5
	AMF+Rh	AMF	33.46	5.4	3240	500	2740	1:5.4
		AZO+PSBs	33.65	5.6	3360	400	2960	1:7.4
	Rhizobium	–	28.14	0.11	66	150	-84	1:-0.5
		AZO+PSBs	30.53	2.5	1500	250	1250	1:5.0
	Uninoculated	Uninoculate	28.03					
		AZO+PSBs	28.46	0.40	240	200	40	1:0.2
120-25-40 kg NPK/ha +8 tonnes FYM/acre	AMF	AMF	30.18	3.5	2100	450	1650	1:3.6
		AZO+PSBs	30.39	3.7	1920	350	1570	1:4.4
	AMF+Rh	AMF	31.86	5.18	3108	500	2608	1:5.2
		AZO+PSBs	31.66	4.98	2988	400	2588	1:6.4
	Rhizobium	–	26.78	0.1	600	150	450	1:3.0
		AZO+PSBs	28.58	1.90	1140	250	890	1:3.5
	Uninoculated	Uninoculate	26.68					
		AZO+PSBs	27.14	0.46	276	200	76	1:0.38
120-50-40 kg NPK/ha +16 tonnes FYM/acre	AMF	AMF	36.86	6.88	4128	450	3678	1:8.1
		AZO+PSBs	34.84	4.86	2916	350	2566	1:7.3
	AMF+Rh	AMF	36.92	6.94	4164	500	3664	1:7.3
		AZO+PSBs	35.27	5.29	3174	400	2774	1:6.9
	Rhizobium	–	31.91	1.93	1158	150	1008	1:6.7
		AZO+PSBs	35.41	5.43	3258	250	3008	1:12.0
	Uninoculated	Uninoculate	29.98					
		AZO+PSBs	30.77	0.79	474	200	274	1:1.3
240-100-80 kg NPK/ha +8 tonnes FYM/acre	AMF	AMF	36.92	5.24	3144	450	2694	1:5.9
		AZO+PSBs	35.17	3.49	2098	350	1748	1:4.9
	AMF+Rh	AMF	36.96	5.28	3168	500	2668	1:5.3
		AZO+PSBs	35.01	3.33	1998	400	1598	1:3.9
	Rhizobium	–	31.98	0.30	180	150	30	1:0.2
		AZO+PSBs	34.7	3.02	1812	250	1562	1.6.2
	Uninoculated	Uninoculate	31.68					
		AZO+PSBs	31.08	0.40	240	200	40	1:0.20

Diammonium phosphate @ Rs 18.0/P; Urea @ Rs 10.61/N; Muriate of potash @ Rs 15.78/ K ; Cost of PSBs +Azospirilium Rs 200/ ha; Cost of mycorrhiza @ Rs 300/ha, Cost of Rhizobium @ Rs 100/- ; FYM @Rs 300/tonne; ICBR, incremental benefit. cost ratio; price of wheat grain @ Rs 500/q; price of straw @Rs 100/q ; x control means, uninoculated at various fertility levels

Table 36 Build up (+)/ depletion(-) of nutrient status due to integrated nutrient management practices in three rotations (wheat- mungbean-wheat; location Gual Pahari)

Fertilizer level	Kharif inoculation	Current inoculation	Gain (+) / loss (-) of major nutrients N	P_2O_5	K_2O
120-50-50 kg NPK/ha +8 tonnes FYM/acre	AMF	AMF	0.123	6 02	14.71
		AZO+PSBs	0.129	5.94	14.37
	AMF+Rh	AMF+Rh	0.147	6.52	16.44
		AZO+PSBs	0.146	6.03	17.41
	Rhizobium	Rhizobium	0.140	5.04	22.26
		AZO+PSBs	0.137	5.70	24.96
	Uninoculated	uninoculated	0.113	4.51	17.86
		AZO+PSBs	0.122	5.04	21.40
120-25-50 kg NPK/ha +8 tonnes FYM/acre	AMF	AMF	0.165	6.72	16.70
		AZO+PSBs	0.177	6.62	15.38
	AMF+Rh	AMF+Rh	0.194	6.26	18.13
		AZO+PSBs	0.197	6.74	17.97
	Rhizobium	Rhizobium	0.148	5.34	11.01
		AZO+PSBs	0.154	6.68	12.67
	Uninoculated	uninoculated	0.136	4.22	4.63
		AZO+PSBs	0.23	6.05	9.41
120-50-50 kg NPK/ha +16 tonnes FYM/acre	AMF	AMF	0.174	5.79	13 10
		AZO+PSBs	0.185	6.60	12.47
	AMF+Rh	AMF+Rh	0.217	7.75	16.95
		AZO+PSBs	0.20	7.60	16.22
	Rhizobium	Rhizobium	0.164	7.87	13.10
		AZO+PSBs	0.170	8.72	13.22
	Uninoculated	uninoculated	0.24	7.91	8.10
		AZO+PSBs	0.163	8.75	11.82
240-100-100 kg NPK/ha +8 tonnes FYM/acre	AMF	AMF	0.213	7.46	19.26
		AZO+PSBs	0.223	7.11	19.07
	AMF+Rh	AMF+Rh	0.234	7.60	17.43
		AZO+PSBs	0.235	7.06	18.40
	Rhizobium	Rhizobium	0.208	6.97	20.13
		AZO+PSBs	0.216	7.53	20.27
	Uninoculated	uninoculated	0.20	5.66	16.83
		AZO+PSBs	0.209	7.97	19.47

Table 37 Effect of fertilizer/manure integrated with indigenous mycorrhiza on soil biochemical characteristics analyzed at wheat harvest grown at Badshahpur site

Treatment		Macronutrients and chemical parameters						Micronutrients			
		pH	EC* (dS/m)	N %	Olsen P (ppm)	K (ppm)	OC (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
F1	Inoculated	7.4	0.32	0 25	13.27	95.0	0.38	51.70	352.06	18119.2	1.61
	Uninoculated	7.17	0.29	0.27	12.23	96.67	0.43	42.07	291.65	16050.8	0.58
F2	Inoculated	7.17	0.34	0.28	13 05	97.66	0 36	47 32	392 41	14524.5	1.73
	Uninoculated	7 12	0.30	0 23	9 63	99.67	0 37	41.86	300.12	17653 0	0.74
F3	Inoculated	7.26	0.44	0.33	17.23	122.6	0.71	66.65	483 30	20883.1	5.40
	Uninoculated	7 32	0.33	0 30	15 32	122.4	0 61	59 81	412.23	20164.6	1 62
F4	Inoculated	7.19	0.38	0.33	15.71	133.6	0.65	51.91	495.28	20102.5	8.30
	Uninoculated	7.22	0.32	0.34	13.88	134.3	0.46	43.89	383.14	19515.5	2.59
LSD (0.05)		0.14	0.06	0.06	2.42	10.78	0.13	5.73	25.75	4045.1	0.89

* electrical conductivity ; means are average of three replicates ; LSD= least significance difference by DMRT (P = 0 05)

Table 38 Soil microbial properties of Badshahpur site analyzed after amendments at wheat harvest

Treatment		*Microbial parameter* Total microbial count (cfu/g)	Dehydrogenases (µg/g/24 hrs)
F1	Inoculated	4.83×10^4	30.46
	Uninoculated	3.78×10^4	26.43
F2	Inoculated	4.35×10^4	37.93
	Uninoculated	3.89×10^4	25.80
F3	Inoculated	4.84×10^4	45.90
	Uninoculated	4.64×10^4	44.43
F4	Inoculated	4.98×10^4	42.03
	Uninoculated	4.52×10^4	41.27
LSD (0.05)		2.6×10^3	5.79

LSD= least significance difference by DMRT; Means are average of three replications

Table 39 Effect of fertilizer/manure on growth of wheat inoculated with mycorrhizae grown at Badshahpur

Treatment		*Agronomic character* Grain yield (q/ha)	Straw yield (q/ha)	Number of tillers/plant	Plant P (%)	Plant N (%)
F1	Inoculated	26.63	33.63	3.63	0.22	0.32
	Uninoculated	24.59	32.83	3.23	0.08	0.30
F2	Inoculated	30.59	38.95	3.84	0.20	0.32
	Uninoculated	22.04	30.79	2.83	0.08	0.29
F3	Inoculated	32.21	40.13	5.06	0.31	0.46
	Uninoculated	30.49	38.38	4.13	0.12	0.42
F4	Inoculated	33.19	41.64	5.10	0.34	0.51
	Uninoculated	30.77	38.55	4.67	0.16	0.35
LSD (0.05)		1.86	1.69	0.36	0.035	0.070

Means are average of three replicates; LSD= least significance difference by DMRT

		Gual Pahari site					
		At zero time		*At 8 months*		*At 20 months*	
Treatment		*GBH (cm)*	*Height (m)*	*GBH (cm)*	*Height (m)*	*GBH (cm)*	*Height (m)*
F1	Inoculated	5.26	2.93	17.3	5.43	29.86	12.40
	Uninoculated	5.36	3 03	17.6	5 52	22 45	10 41
F2	Inoculated	5.52	3.19	17.9	5.51	27.23	12.26
	Uninoculated	5.63	2.96	17 9	5.63	23.46	9 90
F3	Inoculated	5.60	2.93	15.93	5.60	29.10	13.0
	Uninoculated	5.59	2.92	17.40	5.59	28.33	11 2
F4	Inoculated	5 37	3.03	17.93	5 37	29.56	13 48
	Uninoculated	5.28	2.94	15 93	5.28	24.96	10 66
LSD(0.05)		0.73	0.37	2.56	0.73	4.05	1 89

Means are average of three replicates; LSD. least significance difference by DMRT

Table 41 Cost economics of wheat-pulse rotation under Poplar-based agroforestry at Gual Pahari site in an integrated nutrient management trial

Treatment		Gross returns (Rs/year)				Cost of cultivation/plantation/year				B/C ratio	B/C ratio under conventional system
		Wheat	Mung bean	Poplar*	Total	Wheat	Mung bean	Poplar[z]	Total		
F1	Biofertilizer inoc	19800	19420	55000	94220	11216	12512	2306	26034	2.61	0.65
	Uninoculated	15954	13100	55000	84054	10806	12412	2306	25524	2 29	0.25
F2	Biofertilizer inoc.	18612	21920	55000	95532	11056	12062	2306	25424	2.76	0 75
	Uninoculated	15072	19100	55000	74115.7	10556	11662	2306	24524	2.02	0.53
F3	Biofertilizer inoc.	21312	26620	55000	102932	13006	14012	3006	30024	2 43	0 77
	Uninoculated	17988	23040	55000	96028	12806	14112	3006	29924	2.20	0.52
F4	Biofertilizer inoc.	21342	27960	55000	104302	14312	13624	2306	30242	2.45	0 76
	Uninoculated	19008	23500	55000	97508	13812	13424	2306	29542	2.30	0.56

Diammonium phosphate @ Rs 18.0/P, Urea @ Rs 10 61/N, Muriate of potash @ Rs 15.78/K, Cost of PSBs +Azospirillium Rs 100/ha, Cost of mycorrhiza @ Rs 200/ha; Cost of Rhizobium @ Rs 100/- ; FYM @Rs 200/tonne; price of wheat grain @ Rs 500/q; price of straw @Rs 100/q ; Price of mung grain @ Rs 2000/qtl

* Actual cost for poplar plants in various treatments will be extrapolated after 4 years.

Z cost for poplar plantation includes cost for irrigation, ETPs, manuring, pruning, pit digging, planting and overall maintenance, the cost of irrigation per year calculated on the basis of total cost incurred in 10 years, poplar price @ Rs 1000/- per plant calculated per year based on the 10 years as gestation period/maturity

Table 42 Interaction effect of fertility levels and biofertilizers on soil chemical characteristics at urd harvest (wheat-urd rotation, crop urd) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)											
		120-50-50z (current dose 20-0-0)			120-25-50z (current dose 20-0-0)			120-50-50y (current dose. 20-0-0)			240-100-100z (current dose 20-0-0)		
Previous inoculation	Current inoculation	pH	EC (dS/m)	O.C (%)	pH	EC (dS/m)	O.C (%)	pH	EC (dS/m)	O.C (%)	pH	EC (dS/m)	O.C (%)
AMF	AMF	7.17	0.48	0 38	7.23	0.55	0 50	7 28	0 63	0 49	7.29	0.35	0.48
AZO1	–	7 35	0.36	0 45	7 27	0 55	0 53	7.32	0 70	0.54	7.33	0 48	0.53
AZO2	–	7.11	0.60	0 55	7.28	0.53	0.47	7.36	0.80	0.47	7.33	0 65	0 58
PSBs	–	7.30	0.85	0 47	7.32	0 68	0 45	7 19	0 55	0 45	7.16	0.60	0 54
AMF+Rh	AMF+Rh	7.17	0.53	0.41	7.29	0.90	0.33	7.22	0.68	0.48	7.18	0.70	0 58
AZO1	–	7.30	0.33	0 50	7.35	0.80	0.31	7.32	0.68	0.52	7 24	0 85	0 71
AZO2	–	7.34	0.80	0.42	7.32	0.45	0.38	7.19	0.80	0 54	7.34	0.81	0.66
PSBs	–	7.36	0.96	0.45	7.34	0.45	0.38	7.22	0.48	0.55	7 19	0.70	0.61
Rh	Rhizobium	7.13	0.73	0.53	7.26	0.63	0.64	7.10	0.83	0.55	7.34	0.42	0.48
AZO1	–	7.28	0.58	0.47	7.34	0.70	0.43	7.30	0 48	0.40	7.38	0.53	0.64
AZO2	–	7.34	0.53	0.42	7 20	0.80	0 51	7.32	0.53	0 42	7.30	0.45	0.49
PSBs	–	7.28	0.68	0.48	7.21	0.53	0.30	7.20	0.48	0 37	7.21	0.53	0.48
Control	–	7.25	0.58	0.36	7.10	0.95	0.42	7.27	0.35	0.42	7.32	0 68	0.58
AZO1	–	7.24	0.43	0.34	7.31	0.88	0.31	7.27	0.60	0 43	7.33	0.66	0 47
AZO2	–	7.23	0 70	0 52	7 34	0 93	0 45	7.21	0 70	0.40	7.24	0.70	0.32
PSBs	–	7.35	0.73	0.57	7.32	0.58	0 73	7.11	0 43	0.51	7.25	0.35	0.43
LSD (0.05) Fertilizer doses		0.014	0 015	0.04									
LSD (0.05) Inoculations		0.034	0.035	0.05									
Interaction (inoc. × fertility levels)		***	***	***									

Z = FYM was applied @ 5 tonnes/ha; y = FYM applied @10 tonnes/ha

Table 43 Interaction effect of fertility levels and biofertilizers on macronutrients in soil at urd harvest (wheat - urd rotation, crop urd) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)											
		120-50-50z (current dose. 20-0-0)			120-25-50z (current dose: 20-0-0)			120-50-50y (current dose: 20-0-0)			240-100-100z (current dose : 20-0-0)		
Previous inoculation	Current inoculation	N (%)	P_2O_5 (ppm)	K_2O (ppm)	N (%)	P_2O_5 (ppm)	K_2O (ppm)	N (%)	P_2O_5 (ppm)	K_2O (ppm)	N (%)	P_2O_5 (ppm)	K_2O (ppm)
AMF	AMF	0.030	9 04	95 0	0.037	10.46	95.0	0.023	5.76	132.0	0.018	6.90	93 0
AZO1	-	0 037	8.64	96 0	0.041	8 50	96.0	0.027	5.38	154.0	0.023	5.10	97 0
AZO2	-	0.040	9.08	89 0	0 030	8 48	97 0	0 025	5 14	132.0	0.028	4.70	121.0
PSBs	-	0.044	6 40	102.0	0.032	8.50	85.0	0.027	5.16	126.0	0.032	5.30	108.0
AMF+Rh	AMF+Rh	0.033	7.08	106.0	0.027	10.48	89.0	0.028	4 72	135.0	0.037	4.90	115.6
AZO1	-	0.039	10.72	121.0	0.032	7 30	86 0	0.030	4.90	124.0	0.040	5.30	121.0
AZO2	-	0.031	11.36	123.0	0 029	7.30	87.3	0.030	5.12	132.0	0.039	9.04	108.0
PSBs	-	0.045	10 48	104 0	0.030	7.50	94.0	0.031	5 70	125.0	0.031	8 52	97.33
Rh	Rhizobium	0.044	7.08	114.0	0.030	5.30	113.0	0.035	6.48	124.0	0.024	6.50	121.0
AZO1	-	0.037	10.42	113 0	0.045	4.71	108 0	0.037	6.52	126 0	0.027	6.24	105.0
AZO2	-	0.035	10.64	132.0	0.033	9.04	107.0	0.030	5.08	102.0	0.025	6.42	107 0
PSBs	-	0 037	8.50	98.0	0 031	10.42	105.0	0.022	7.08	122.0	0.022	7.30	95.0
Control	-	0.032	8.99	102.0	0.030	4.75	108.67	0 017	7.32	102.0	0.029	6.51	132.0
AZO1	-	0.025	8.48	132.0	0.028	8.48	112.0	0.023	7.12	108.0	0.033	6.24	115 0
AZO2	-	0.036	8 68	103.3	0.037	7.03	115.0	0.027	6.84	107.0	0.021	6.30	118.0
PSBs	-	0.042	8.64	121.0	0 53	10.70	126.0	0.030	7.50	102.0	0.026	6.34	114.0
LSD (0.05) Fertilizer doses		0.007	0 35	6.07									
LSD (0.05) Inoculations		0.013	0.59	7.19									
Interaction (inoc. × fertility levels)		***	***	***									

Z = FYM was applied @ 5 tonnes/ha; y = FYM applied @10 tonnes/ha

Table 44 Interaction effect of fertility levels and biofertilizers on changes in micronutrients in soil at urd harvest (wheat-urd rotation, crop urd) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)															
		120-50-50z (current dose. 20-0-0)				120-25-50z (current dose: 20-0-0)				120-50-50y (current dose: 20-0-0)				240-100-100z (current dose. 20-0-0)			
Previous inoculation	Current inoculation	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
AMF	AMF	154.32	442.18	16666.3	13.03	466.48	406.28	16795.1	14.73	274.7	449.0	16650.6	18.16	127.38	484.84	16985.7	12.65
AZO1	–	363.04	430.18	16873.6	10.75	228.08	510.28	16507.2	13.76	332.7	502.67	16988.8	23.86	128 82	451.59	17288 2	13 15
AZO2	–	130.18	463.0	16595.3	12.57	336.16	465.15	16431 3	24.48	153 6	446.22	17052.5	18 82	144.81	532 85	17608 0	13.99
PSBs	–	115.97	479.98	16696.7	11.85	187.29	385.47	16940.2	15.57	119.6	445 48	16754.0	14.88	102.37	483.83	17749.9	13.64
AMF+Rh	AMF+Rh	108.62	504.26	17261.7	11.93	196.87	371.59	16546.7	13 16	404.2	454 60	16853.2	23 77	103.35	424 38	17773.8	13 73
AZO1	–	258.92	376.88	17281 5	15.36	171.48	430.12	16648.9	15.42	263.6	451.87	16668.5	13.85	107.02	430.08	17520.3	15.07
AZO2	–	173.56	664.08	17377.1	36.93	147.33	404.31	17126.6	14.09	406 0	416.88	16497.2	13.43	101.19	378.45	17708.1	12.44
PSBs	–	162.71	653.02	17675.6	34.28	543.70	412.28	17404.9	15.32	194.9	348.04	16820.7	13.39	382.64	437.45	17560.6	12.83
Rh	Rhizobium	639.29	428.41	17046.6	12.69	157.50	368.24	16446.0	12.07	246.7	455.17	16989.5	18.08	835.38	532.58	16476.9	12.55
AZO1	–	161.38	512.14	17125.2	9.73	348.79	430.87	16998.1	14.33	352.5	431.32	17049.9	15.14	156.76	453.75	16634.7	12.12
AZO2	–	165.06	369.16	16650.4	12.65	610.6	442.70	17251.0	13.85	186.2	473.28	16797.3	14.73	161.57	438.46	16674.0	14.17
PSBs	–	768.78	418.61	16577.1	12.43	242.46	531.82	17057.5	15.05	252.8	338.14	16851.0	17.96	146.29	471.44	16533.0	14.64
Control	–	334.94	382.39	17650.6	14.52	153.13	378.94	17423.5	18.89	226.0	442.65	16637.0	14.32	159.18	412.23	16189.8	15.96
AZO1	–	160.99	480.99	17447.9	13.25	172.87	362.17	17067.2	17.28	167.9	445.72	17347.6	14.31	157.63	407.12	16468.9	12.07
AZO2	–	174.95	446.01	17451.7	12.21	227.50	426.30	16584.5	15.59	175.1	418.48	16707.0	15.60	153 82	680.24	16579.9	13.33
PSBs	–	177.48	430.17	16705.1	12.16	164.74	438.36	16781.7	14.75	641.6	419.68	16798.8	17.78	355.44	447.04	17432.5	15.58
LSD (0.05) Fertilizer doses		12.21	3.20	115.02	0.46												
LSD (0.05) Inoculations		11.74	9 41	135.73	1.14												
Interaction (inoc. × fertility levels)		***	***	***	***												

Z = FYM was applied @ 5 tonnes/ha; y = FYM applied @10 tonnes/ha

Table 45 Interaction effect of fertility levels and biofertilizers on nutrient uptake in urd plants at harvest (wheat-urd rotation, crop urd) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)															
		120-50-50z (current dose: 20-0-0)				*120-25-50z (current dose: 20-0-0)*				*120-50-50y (current dose: 20-0-0)*				*240-100-100z (current dose: 20-0-0)*			
Previous inoculation	Current inoculation	*Zn (ppm)*	*Mn (ppm)*	*Fe (ppm)*	*Cu (ppm)*	*Zn (ppm)*	*Mn (ppm)*	*Fe (ppm)*	*Cu (ppm)*	*Zn (ppm)*	*Mn (ppm)*	*Fe (ppm)*	*Cu (ppm)*	*Zn (ppm)*	*Mn (ppm)*	*Fe (ppm)*	*Cu (ppm)*
AMF	AMF	56.10	75.58	2881.3	13.69	54.22	68.49	2818.8	13.2	103.9	86.96	4935.9	19.5	158.48	102.58	4824.30	25.42
AZO1	–	78.84	76.74	3463.5	22.05	75.92	76.09	3401.2	20.64	115 01	103.62	6251.0	33.88	169.82	131.31	6323.4	26.08
AZO2	–	75.44	72.58	3357.5	8.98	73.49	69.15	3356.5	9.71	76.21	82.78	3221.0	14.91	126.97	130.94	9463.36	21.71
PSBs	–	62.62	76.25	1459 2	12.62	62.32	70.02	1458.7	12.85	74.55	73.83	3974.7	21.21	137.03	113.72	7663.40	21.42
AMF+Rh	AMF+Rh	64.87	77.25	1506.3	21.65	63.87	74.79	1458.6	21.59	94 33	83.83	4031.7	22.0	160.3	132.51	6060.60	38.58
AZO1	–	73.80	35.76	1873.5	22.97	73.31	37.73	1828.4	21.96	84.81	62.34	3155.2	23.36	195.15	124.40	9064.10	27.73
AZO2	–	104.51	73.85	3148.5	25.45	102.98	71.52	3145.1	25.71	95.37	88.16	6325.9	20.59	163.6	113 58	7674.96	24.7[illegible]
PSBs	–	104.42	111.90	4358.2	28.33	103.09	102.4	4254.7	25.54	104.2	97.34	3810.3	21.41	168.2	118.52	8182.82	27.25
Rh	Rhizobium	81.14	92.11	4819.1	12.32	80.22	91.15	4780.2	9.86	85.31	97.83	2388.5	26.51	243.39	161.65	9457.90	23 9[illegible]
AZO1	–	78.42	27.15	2656.7	13.57	76.75	29.27	2621.5	12.67	113.57	75.25	4113.9	33.25	137.4	97.92	6449.8	24.21
AZO2	–	80.75	86.64	4455.6	15.65	79.35	84.68	4427.9	13.82	132.88	63.29	5139.1	32.03	229.85	113.94	8230.30	25.7[illegible]
PSBs	–	77.20	75.22	3750.0	14.26	76.6	75.31	3654.9	13.37	127.55	93.63	6124.8	20.52	173.25	118.61	7843.80	33.4[illegible]
Control	–	74.52	53.25	2940.5	15.05	74.45	51.69	2862.3	13.47	106.52	31.09	2030.1	35.44	173.94	65.52	5516 70	24.6[illegible]
AZO1	–	68.44	43.25	2799.9	13.12	66.06	44.05	2747.2	12.54	103.46	71.87	2520.9	33.21	152.82	122.78	4850.10	24.7[illegible]
AZO2	–	65.62	42.91	4650.5	13.19	65.10	42.95	4610.5	12.47	304.3	43.92	2477.8	56.37	103.73	106.71	4868.60	22.7[illegible]
PSBs	–	87.24	75.69	5525.0	18.63	84.98	75.28	5394.8	14.68	49.42	31 87	2908.4	42.51	139.14	122 92	8131.10	18.8[illegible]
LSD (0.05) Fertilizer doses		3.10	2.09	63.5	1.40												
LSD (0.05) Inoculations		5.46	10.03	74.8	2.08												
Interaction (inoc. × fertility levels)		***	***	***	***												

Z = FYM was applied @ 5 tonnes/ha; y = FYM applied @10 tonnes/ha

Table 46 Interaction effect of fertility levels and biofertilizers on phosphorus uptake of urd at harvest (wheat-urd rotation, crop urd) location: Gual Pahari

Inoculation		*Fertilizer applied levels (NPK/ha)*			
Previous inoculation	Current inoculation	*120-50-50z (current dose: 20-0-0)*	*120-25-50z (current dose. 20-0-0)*	*120-50-50y (current dose: 20-0-0)*	*240-100-100z (current dose. 20-0-0)*
AMF	AMF	0.053	0.068	0.10	0.091
AZO1	–	0 064	0.082	0 11	0.065
AZO2	–	0.046	0 055	0.10	0.064
PSBs	–	0 068	0.073	0 11	0.10
AMF+Rh	AMF+Rh	0.046	0.051	0 087	0.11
AZO1	–	0.058	0.060	0 10	0.075
AZO2	–	0.054	0.051	0 094	0.087
PSBs	–	0.074	0.060	0.099	0.11
Rh	Rhizobium	0.032	0.051	0 087	0.062
AZO1	–	0.040	0.073	0.094	0.067
AZO2	–	0.036	0.048	0.089	0.066
PSBs	–	0.046	0.051	0.10	0 11
Control	–	0.021	0.058	0.061	.061
AZO1	–	0.029	0.074	0.085	0 070
AZO2	–	0.036	0.049	0.091	0 063
PSBs	–	0.043	0 060	0 10	0.074
LSD (0.05) Fertilizer doses		0.0041			
LSD (0.05) Inoculations		0.0094			
Interaction (inoc. × fertility levels)		**			

Z = FYM was applied @ 5 tonnes/ha; y = FYM applied @10 tonnes/ha

Table 47 Interaction effect of fertility levels and biofertilizers on microbial activity in soil at urd harvest (wheat-urd rotation, crop: urd) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)							
		120-50-50z (current dose : 20-0-0)		120-25-50z (current dose: 20-0-0)		120-50-50y (current dose : 20-0-0)		240-100-100z (current dose : 20-0-0)	
Previous inoculation	Current inoculation	Total culturable micobial count (cfu/g soil)	Soil dehydrogenases activity (TPF μg/g/24hrs)	Total culturable micobial count (cfu/g soil)	Soil dehydrogenases activity (TPF μg/g/24hrs)	Total culturable micobial count (cfu/g soil)	Soil dehydrogenases activity (TPF μg/g/24hrs)	Total culturable micobial count (cfu/g soil)	Soil dehydrogenases activity (TPF μg/g/24hrs)
AMF	AMF	6.31×10^5	447.13	6.36×10^5	448 76	8.07×10^5	267.83	7.69×10^5	312.73
AZO1	–	6.89×10^5	374 33	7.45×10^5	462.56	$8\ 55\times 10^5$	267.20	$8\ 12\times 10^5$	264 37
AZO2	–	6.56×10^5	433.06	$6\ 65\times 10^5$	449.30	$7\ 88\times 10^5$	279.67	$7\ 96\times 10^5$	268.60
PSBs	–	6.75×10^5	412.0	6.28×10^5	413.63	9.35×10^5	346.73	8.13×10^5	301 53
AMF+Rh	AMF+Rh	7.51×10^5	273.03	$6\ 39\times 10^5$	425.83	9.51×10^5	277.70	$8\ 88\times 10^5$	224 37
AZO1	–	7.23×10^5	335.60	6.97×10^5	481.17	9.14×10^5	303.73	$8\ 43\times 10^5$	379 67
AZO2	–	$7\ 21\times 10^5$	374.63	5.99×10^5	462.90	8.18×10^5	284.67	8.78×10^5	228.50
PSBs	–	9.56×10^5	391.70	8.26×10^5	410.13	11.71×10^5	262 40	$10\ 66\times 10^5$	241.43
Rh	Rhizobium	6.12×10^5	526.0	5.55×10^5	426.63	7.56×10^5	413.93	$7\ 89\times 10^5$	346 77
AZO1	–	$6\ 39\times 10^5$	346.97	$5\ 83\times 10^5$	412 87	8.34×10^5	391.73	8.32×10^5	303.06
AZO2	–	5.87×10^5	401.30	5.05×10^5	426.90	7.80×10^5	347 27	$6\ 81\times 10^5$	340 27
PSBs	–	$9\ 55\times 10^5$	496.90	8.08×10^5	431.57	10.73×10^5	420.17	10.62×10^5	246 03
Control	–	4.94×10^5	359 87	3.98×10^5	448.53	$5\ 65\times 10^5$	500.40	5.57×10^5	281.37
AZO1	–	7.85×10^5	401.83	6.89×10^5	427.86	$9\ 24\times 10^5$	395.03	9.08×10^5	371.33
AZO2	–	8.07×10^5	371.93	7.75×10^5	428.67	$9\ 51\times 10^5$	276.80	$8\ 72\times 10^5$	315.0
PSBs	–	10.81×10^5	361.43	10.62×10^5	443.60	$10\ 84\times 10^5$	311 43	$11\ 15\times 10^5$	222.37
LSD (0.05) Fertilizer doses		0.40×10^5	39.34						
LSD (0.05) Inoculations		0.95×10^5	23.90						
Interaction (inoc. × fertility		***	***						

Z = FYM was applied @ 5 tonnes/ha, y = FYM applied @10 tonnes/ha

Table 48 Interaction effect of fertility levels and biofertilizers on growth and grain yield of urd at harvest (wheat-urd rotation ; crop : urd) location: Gual Pahari

Inoculation		Fertilizer applied levels (NPK/ha)											
		120-50-50z (current dose : 20-0-0)			120-25-50z (current dose: 20-0-0)			120-50-50y (current dose : 20-0-0)			240-100-100z (current dose : 20-0-0)		
Previous inoculation	Current inoculation	Grain yield (Kg/ha)	No. of pods /plant	Nodule N %	Grain yield (Kg/ha)	No. of pods /plant	Nodule N %	Grain yield (Kg/ha)	No. of pods /plant	Nodule N %	Grain yield (Kg/ha)	No. of pods /plant	Nodule N %
AMF	AMF	598.0	31 06	0 29	590 67	25 83	0 30	712.67	32.13	0.30	703.33	32.96	0 31
AZO1	–	557 33	24.80	0 25	531.67	26.63	0.26	666.67	26.26	0.28	652.33	27.03	0 28
AZO2	–	510 0	23 33	0.25	488.67	21.83	0.25	612.0	25.83	0.27	615.0	26 16	0 26
PSBs	–	514 67	26 70	0 24	501.33	24.80	0.24	624.33	25 26	0.28	624 33	28.03	0.26
AMF+Rh	AMF+Rh	817.33	37.70	0.38	741.33	35.06	0.37	913.33	40.5	0.43	912.0	38.60	0.39
AZO1	–	576.0	26.69	0 23	542.67	24.90	0.24	676.67	28 83	0 27	685.33	28 50	0.26
AZO2	–	523.0	25.43	0.24	509.0	23.36	0.25	629.0	28 60	0.27	632.33	27.36	0 26
PSBs	–	574.0	26.43	0.22	553.33	24.03	0.22	682.33	28.36	0.26	696.67	28.76	0 25
Rh	Rhizobium	637.67	35.86	0.39	598.33	33.36	0.36	730.0	37.10	0.42	748.33	37.33	0 42
AZO1	–	484.67	25.33	0.25	478.33	24.30	0.25	586.67	26 93	0.28	586.0	27.53	0.28
AZO2	–	494.0	24.03	0.22	488.33	23.06	0.22	598.33	26.03	0.25	607.67	26.10	0.24
PSBs	–	497.0	26.9	0.24	480.33	24.73	0.23	610.0	27.63	0.27	604.67	30 10	0 26
Control	–	363.0	19.83	0.23	352 0	18.26	0.23	442.33	21.83	0.26	485.67	22.16	0.27
AZO1	–	396.67	24.70	0.25	385.0	22.40	0.25	494.67	27.36	0.27	490.0	27.26	0.28
AZO2	–	401.67	24.2	0.23	390.33	22.26	0.23	492.67	27.26	0.25	511.0	26.70	0.26
PSBs	–	414.33	24.83	0.23	398.0	23.10	0.23	513.33	27 36	0.26	519.33	27 10	0.27
LSD (0.05) Fertilizer doses		14.95	0.84	0.01									
LSD (0.05) Inoculations		25.31	2.65	0.02									
Interaction (inoc. × fertility levels)		***	****	**									

Z = FYM was applied @ 5 tonnes/ha; y = FYM applied @10 tonnes/ha

Table 49 Build up (+)/ depletion(-) of nutrient status due to integrated nutrient management practices in three rotations (wheat- mungbean-wheat-urd ; location Gual Pahari)

Fertilizer level	Inoculation		Gain (+) / loss (-) of major nutrients		
	Previous	Current	N	P_2O_5	K_2O
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dose I (Wheat NPK-100,50,50; Mung bean only N and P 20,50; Wheat-120,50,50 and for Urd only 20 kg N/ha +5 tonnes of FYM for each crop	AZO+PSBs	–	0.0174	5.54	11.61
	AMF+Rh	AMF+Rh	0.017	5.71	15.2
	AZO+PSBs	–	0.017	6.29	19.0
	Rhizobium	Rhizobium	0.019	4.61	22.13
	AZO+PSBs	–	0.017	5.79	24.24
	uninoculated	Control	0.030	4.73	15.84
	AZO+PSBs	–	0.037	4.98	22.67
	AMF	AMF	0.019	6.71	13.20
DoseII (Wheat NPK-100,25,50; Mung bean only N and P 20, 25; Wheat-120,25,50 and for Urd only 20 kg N/ha +5 tonnes of FYM for each crop	AZO+PSBs	–	0.020	6.14	11.76
	AMF+Rh	AMF+Rh	0.019	6.37	12.77
	AZO+PSBs	–	0.020	5.95	12.69
	Rhizobium	Rhizobium	0.016	4.38	13.43
	AZO+PSBs	–	0.018	6.08	13.09
	uninoculated	Control	0.015	4.16	8.52
	AZO+PSBs	–	0.018	5.78	13.40
	AMF	AMF	0.0165	4.84	19.75
Dose III (wheat NPK-100,50,50; Mung bean only N and P 20,50; Wheat-120,50,50 and for Urd only 20 kg N/ha +10 tonnes of FYM for each crop	AZO+PSBs	–	0.018	5.32	20.59
	AMF+Rh	AMF+Rh	0.021	5.90	23.0
	AZO+PSBs	–	0.021	6.07	20.84
	Rhizobium	Rhizobium	0.018	6.58	17.75
	AZO+PSBs	–	0.017	7.15	15.99
	uninoculated	Control	0.013	6.82	8.87
	AZO+PSBs	–	0.017	7.41	12.21
	AMF	AMF	0.018	6.37	14.72
Dose IV (wheat NPK-200,100, 100; Mung bean only N and P 80,100; Wheat-240,100,100 and for Urd only 40 kg N/ha +5tonnes of FYM for each crop	AZO+PSBs	–	0.021	5.65	18.46
	AMF+Rh	AMF+Rh	0.024	5.98	18.85
	AZO+PSBs	–	0.024	6.75	17.91
	Rhizobium	Rhizobium	0.019	5.91	22.27
	AZO+PSBs	–	0.020	6.36	17.71
	uninoculated	Control	0.020	5.68	23.31
	AZO+PSBs	–	0.021	6.61	20.46

4

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5 Annexures

A. Inoculum production of AM fungi in greenhouse

B. Layout and field preparation for wheat trial at Gual Pahari experimental site

C. Wheat crop along with poplar mother beds at Gual Pahari site

D. Close view of wheat ears showing healthy ears

E. Wheat (2^{nd} rotation) with poplar-based agroforestry system at Gual Pahari site

F. Wheat crop with treatment plots at farmer's field Badshahpur, Haryana

G. A fully matured wheat crop at farmer's field Badshahpur, Haryana

H. Poplar-based agroforestry system intercropped with wheat at Gual Pahari site, Haryana

I. Production of poplar ETPs in mother beds at Gual Pahari site

J. Mung bean field trial with eucalyptus-poplar based agroforestry system at Gual Pahari site

K. Layout of eucalyptus-poplar based agroforestry system at Gual -Pahari site

L. Layout of poplar-based agroforestry system at farmer's field at Badshahpur site

M. Layout of a representative block (mung bean trial) at Gual Pahari site

N. Layout of a representative block for poplar-mung bean trial at Badshahpur site

O. Layout of a representative block wheat (2nd rotation) trial at Gual Pahari site

P. Layout of a representative block for wheat (2nd rotation) trial at Badshahpur site

Q. Layout of a representative block urd (2nd rotation) trial at Gual Pahari site.

R. Gual Pahari site view after harvesting of Urd.

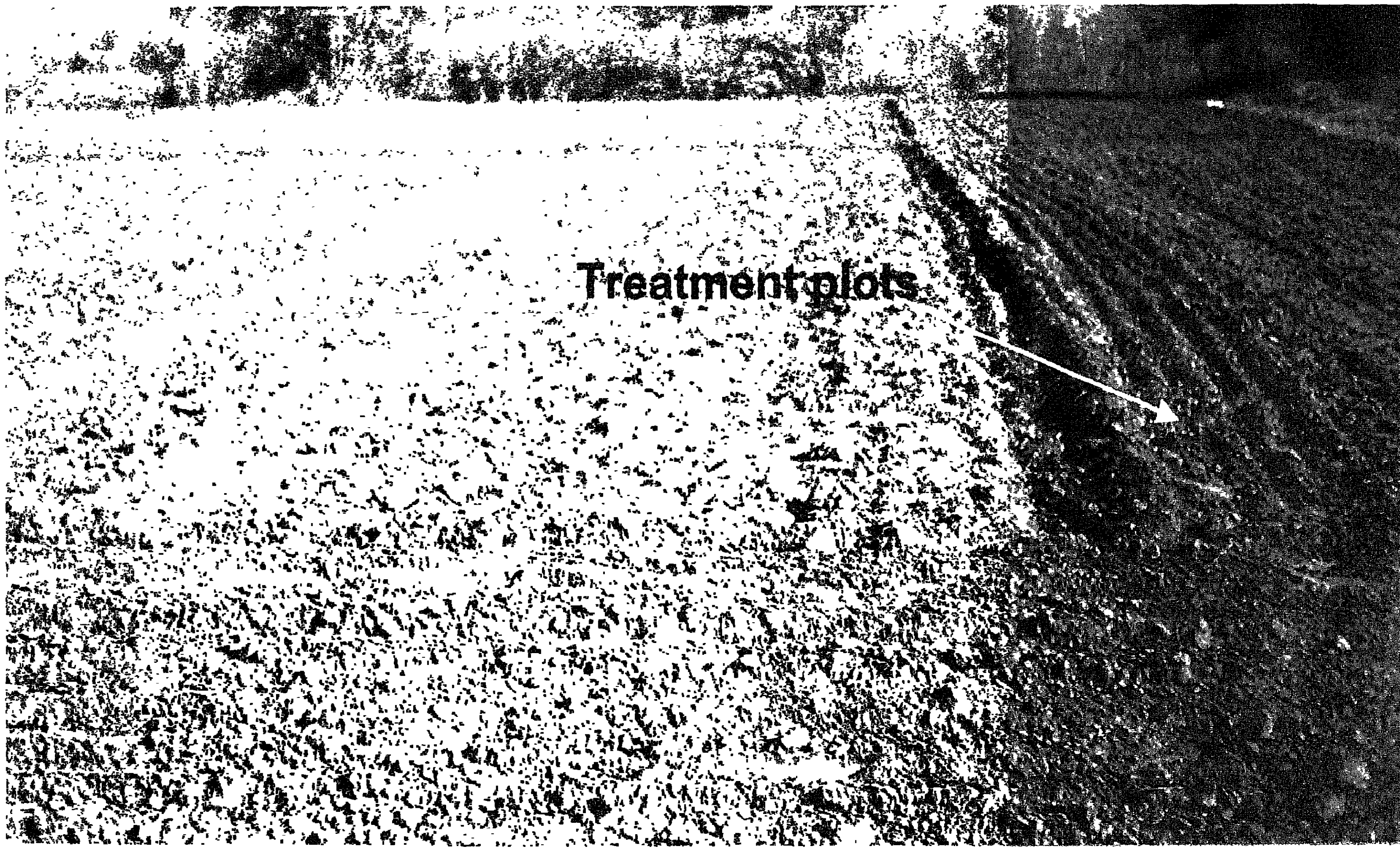
S. Potato trial view at Gual Pahari

Annexure - A

Inoculum production of AM fungi in greenhouse

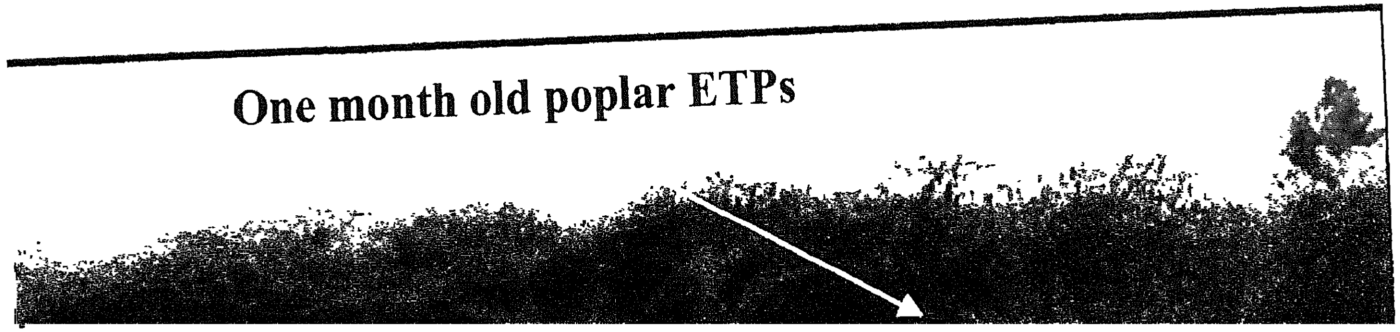
Annexure - B

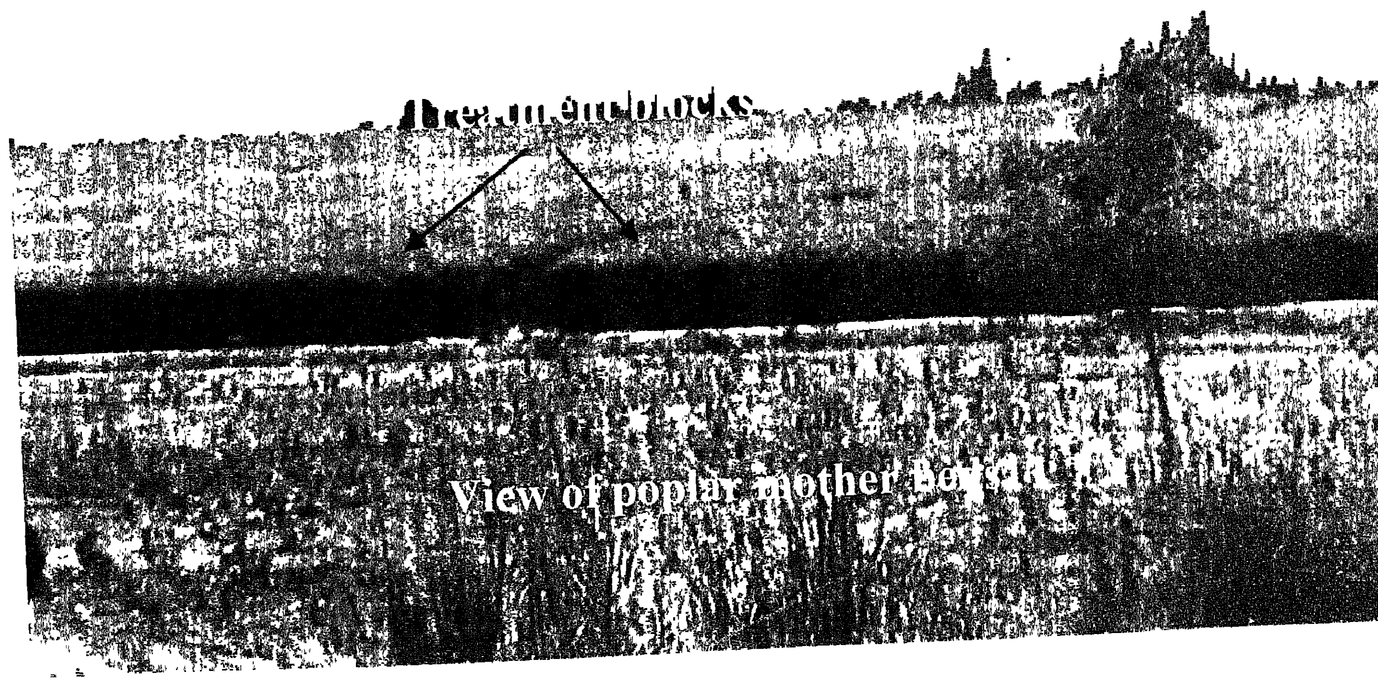
Layout and field preparation for wheat trial at Gual Pahari, Haryana



Annexure - C

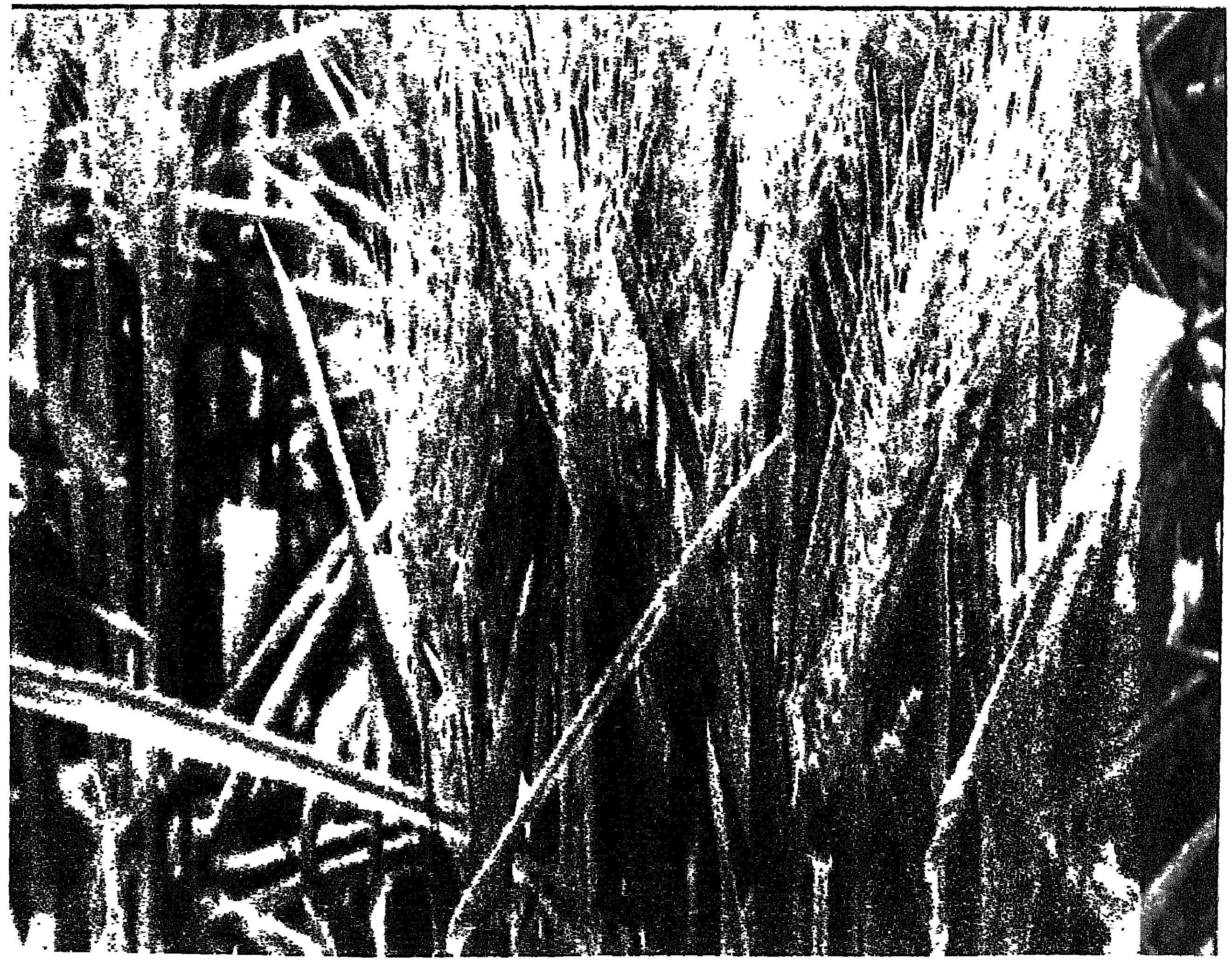
Wheat crop along with poplar mother beds at Gual Pahari, Haryana





Annexure - D

Close view of wheat ears showing healthy ears

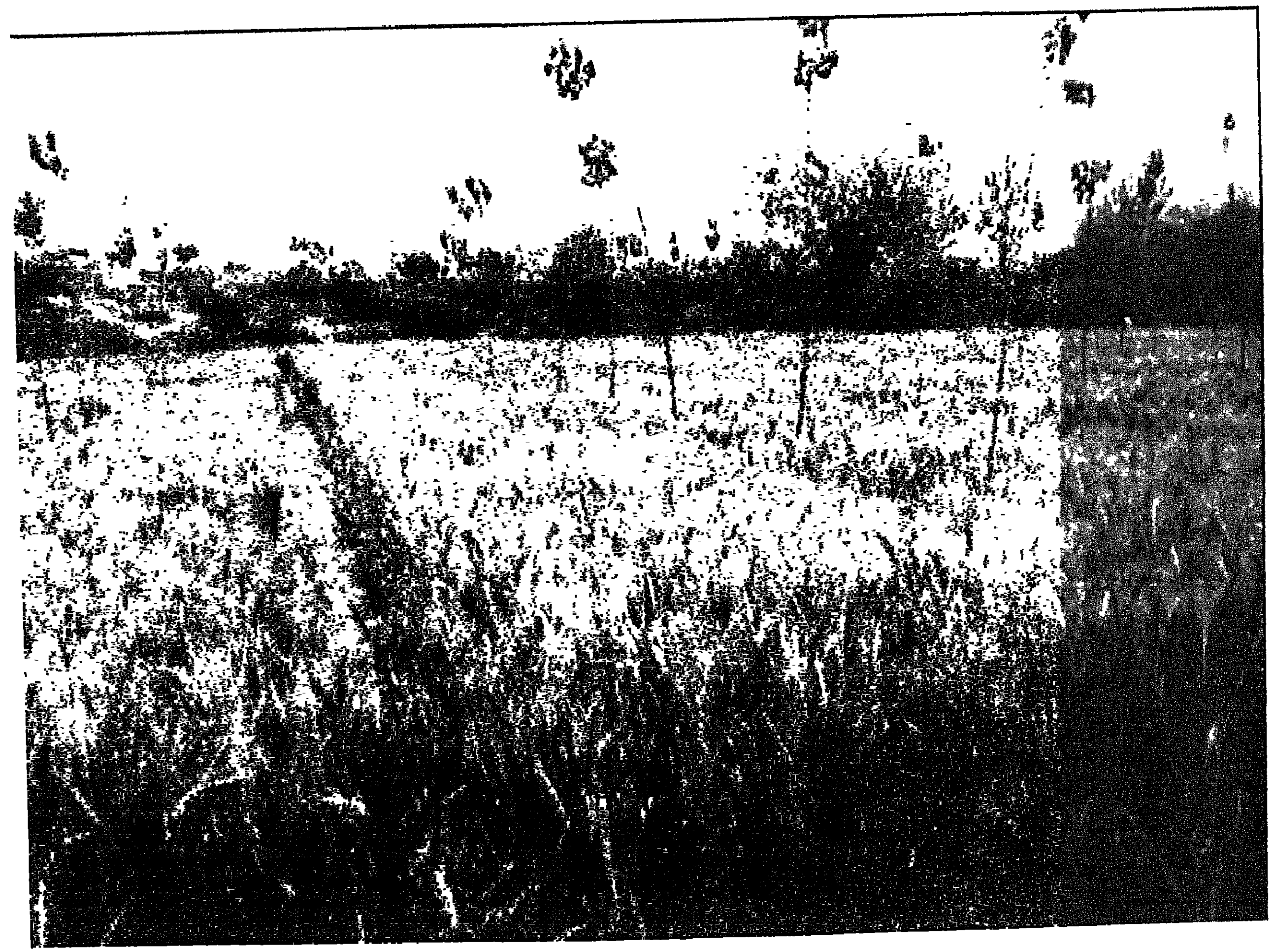


Annexure - E

Wheat (2nd rotation) with poplar based agroforestry system at Gual Pahari, Haryana

Annexure - F

Wheat crop with treatment plots at Badshahpur, Haryana



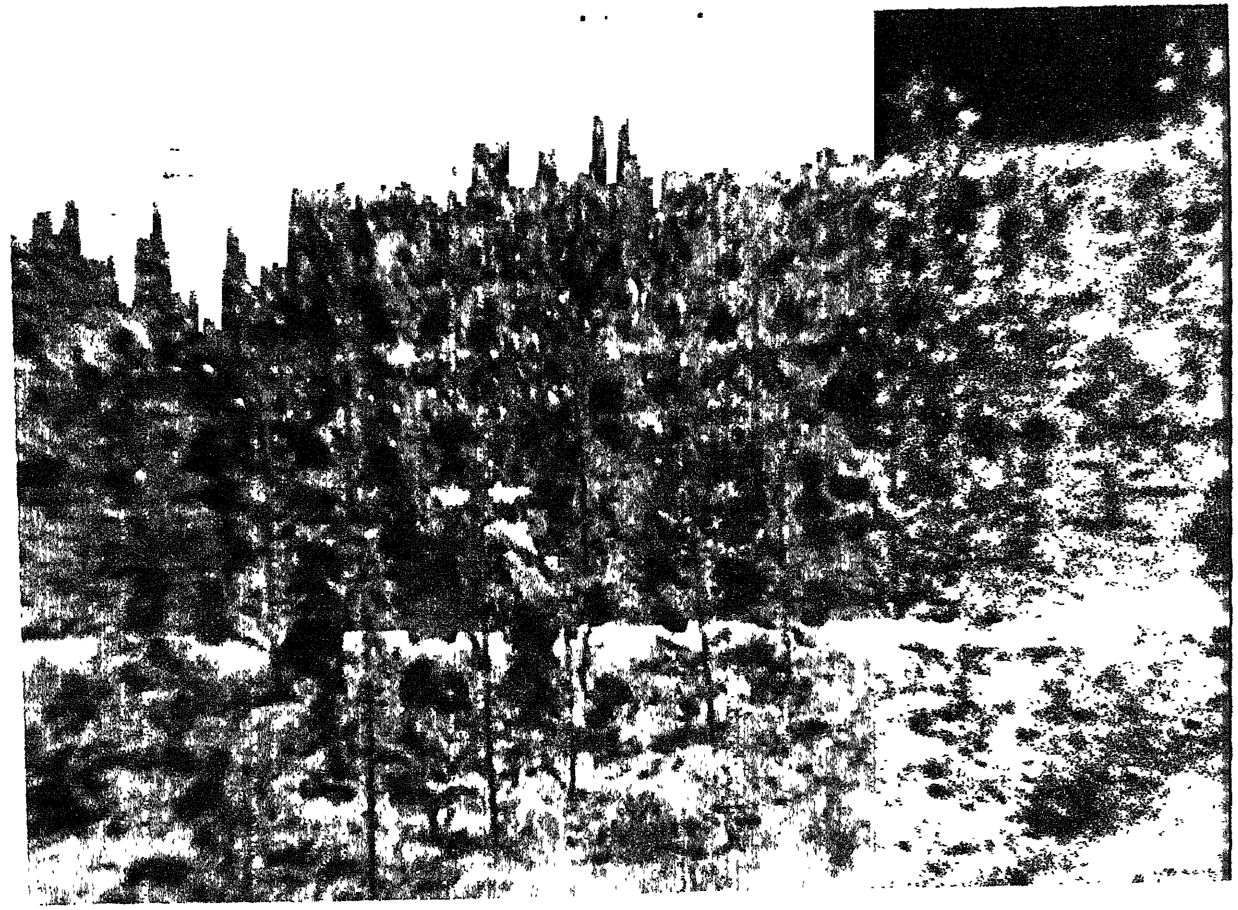
Crop is ready to harvest

Annexure - H

Poplar-based Agroforestry System intercropped with Wheat

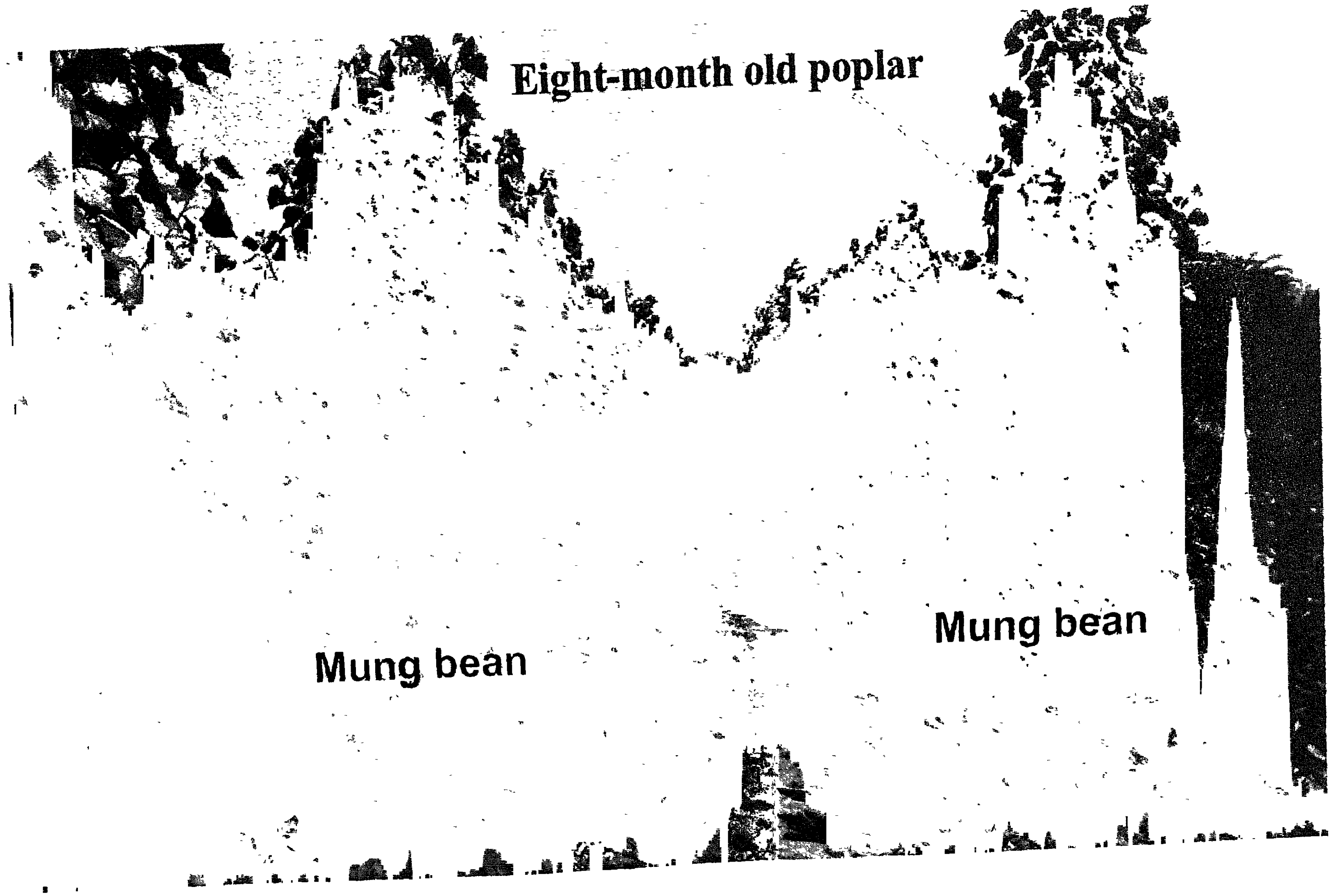
Annexure - I

Production of poplar ETPs in mother beds at Gual Pahari, Haryana



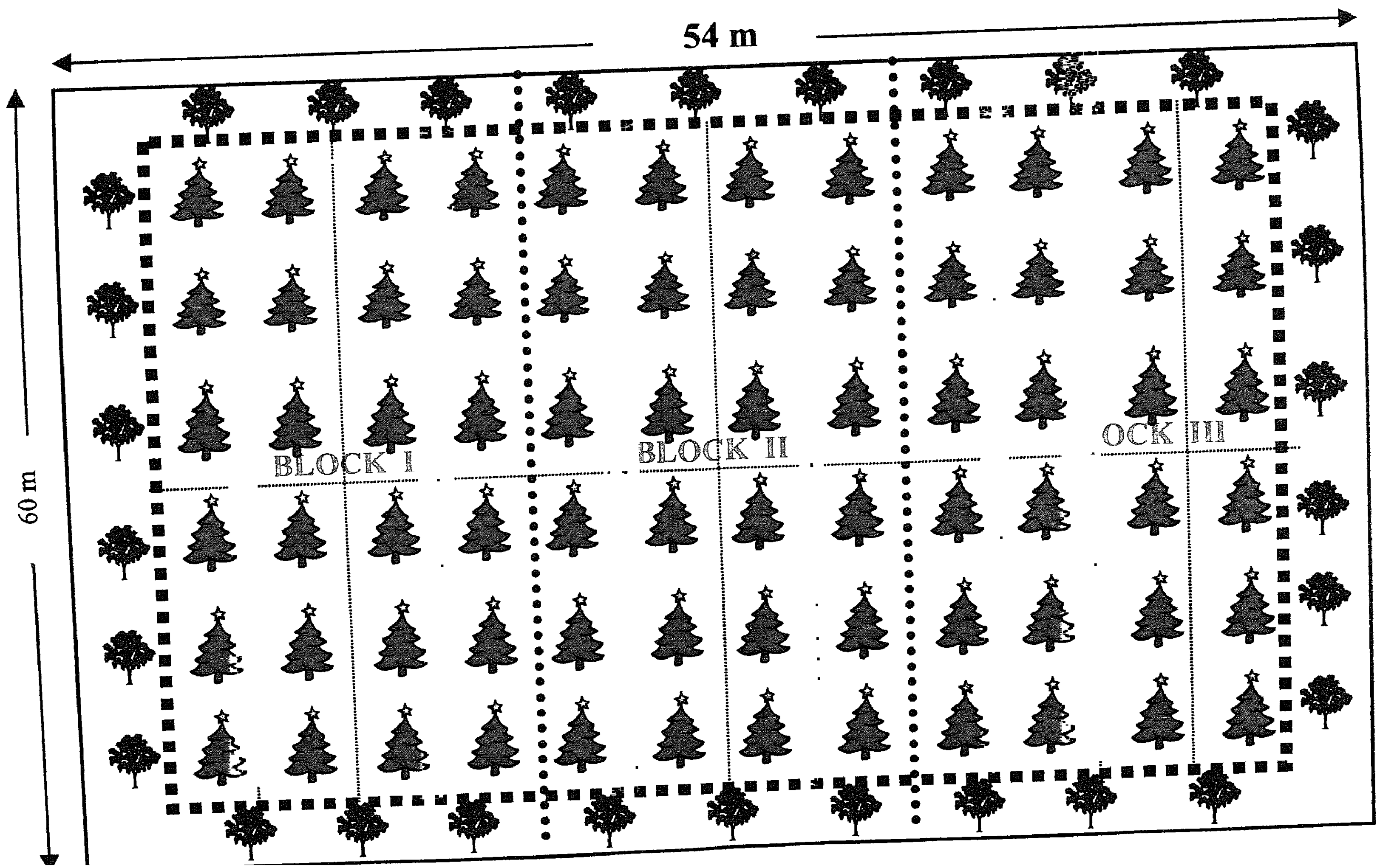
Annexure - J

Mung bean with poplar based agroforestry system at Gual Pahari, Haryana



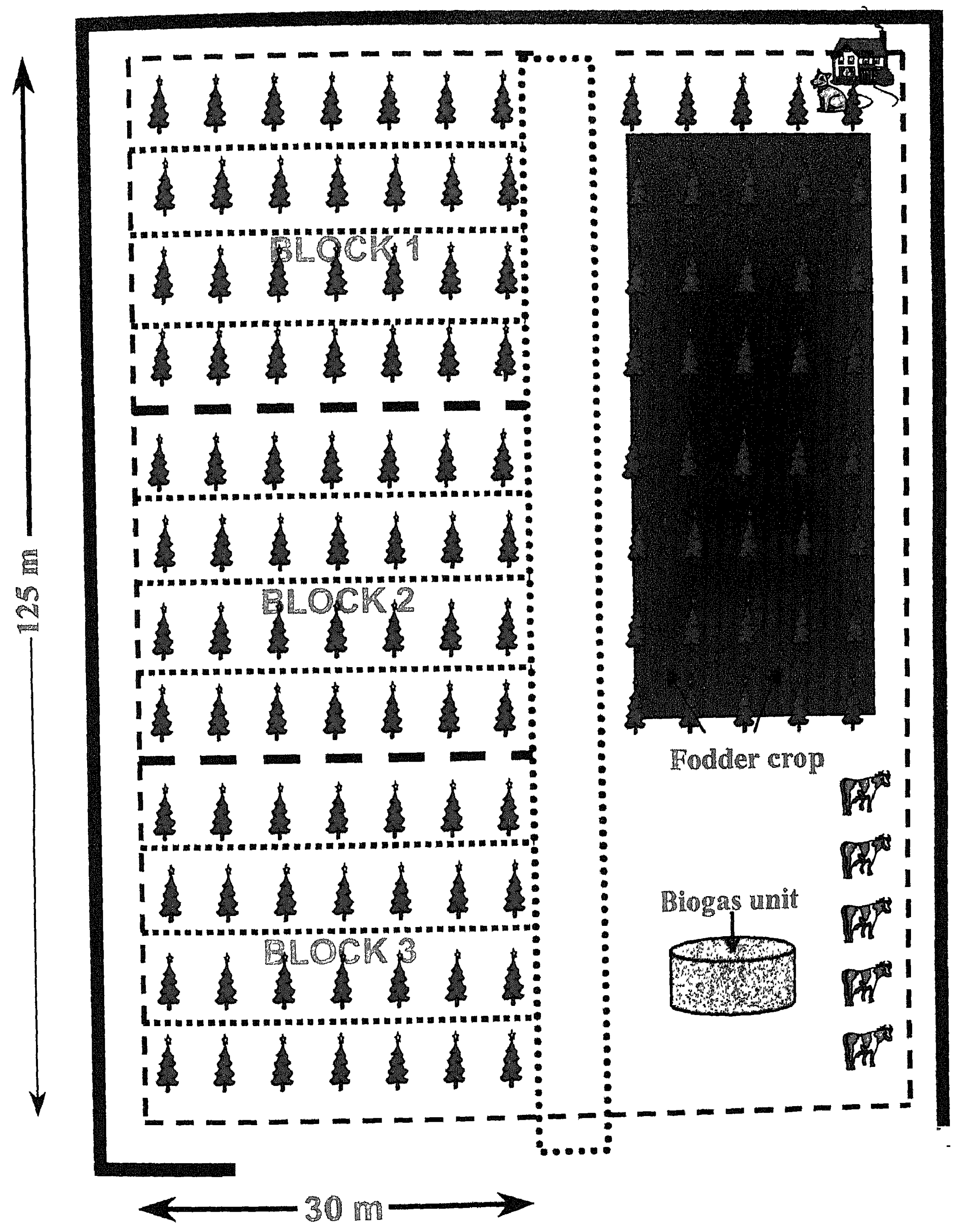
Annexure - K

Layout of eucalyptus-poplar based agroforestry system at Gual Pahari, Haryana



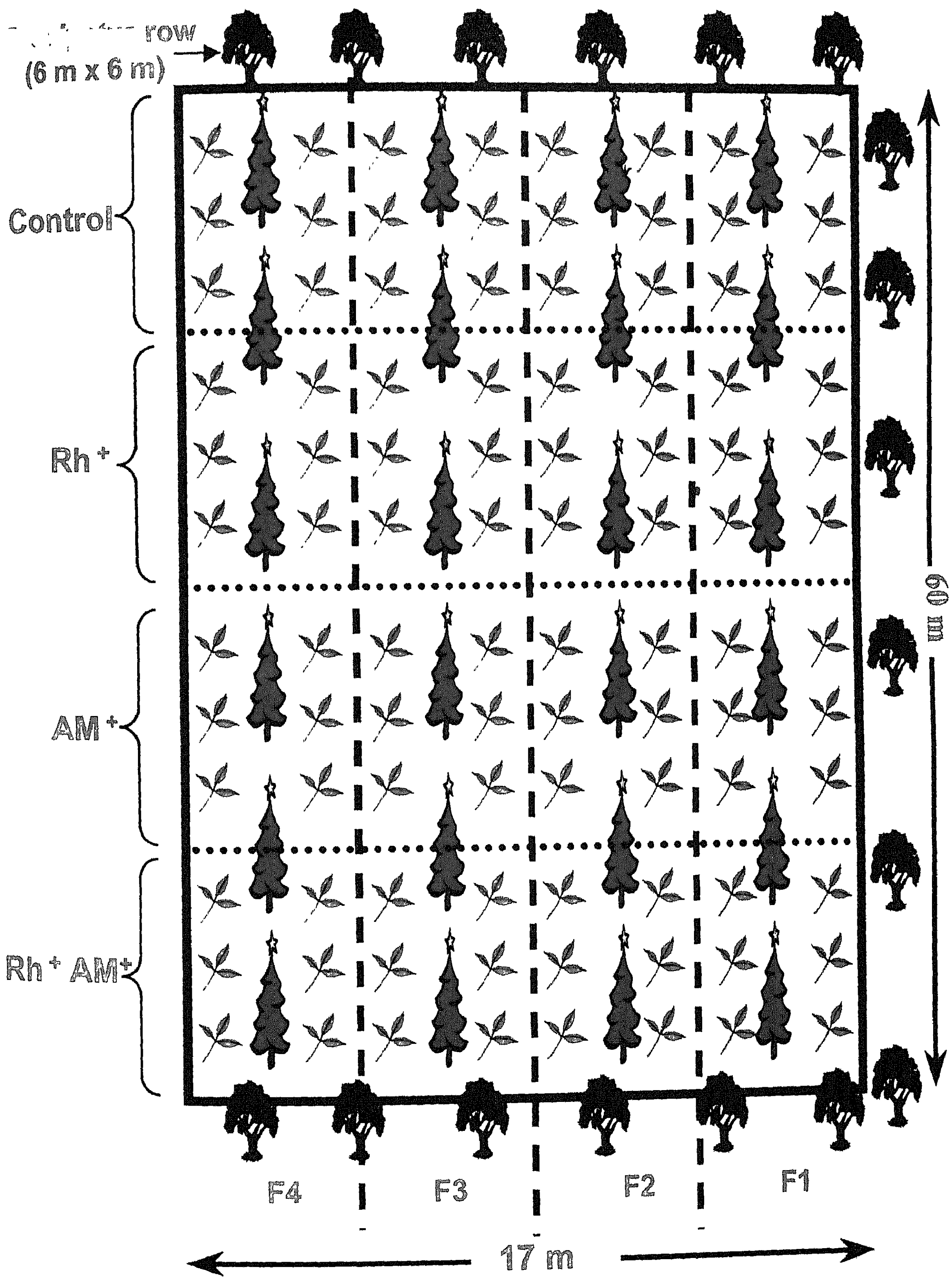
Annexure - L

Layout of poplar-based agroforestry system at farmer's field, Badshahpur, Haryana



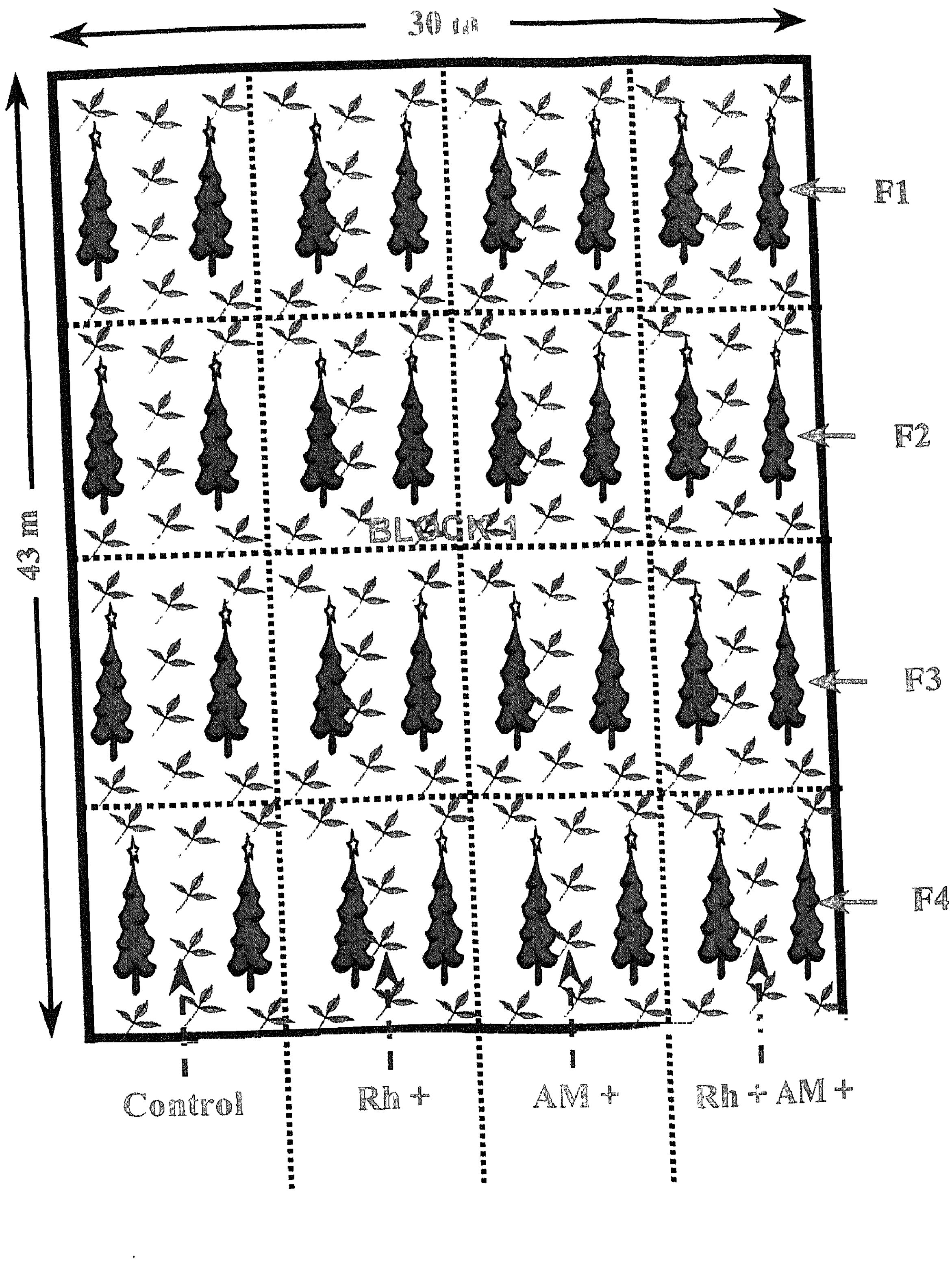
Annexure - M

Layout of a representative block (mung bean trial at Gual Pahari)



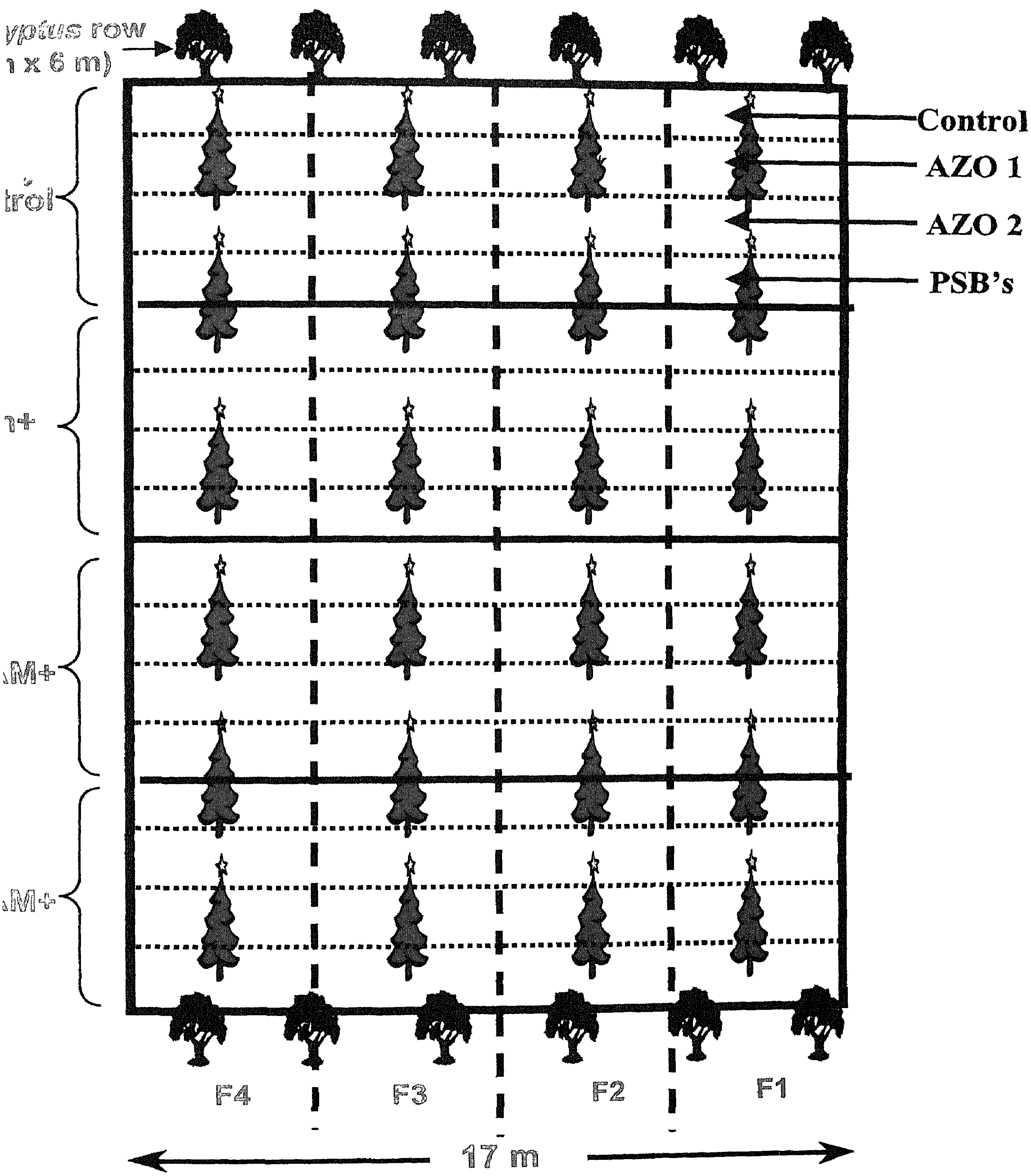
Annexure - N

Layout of a representative block for poplar-mung bean trial at Badshahpur, Haryana



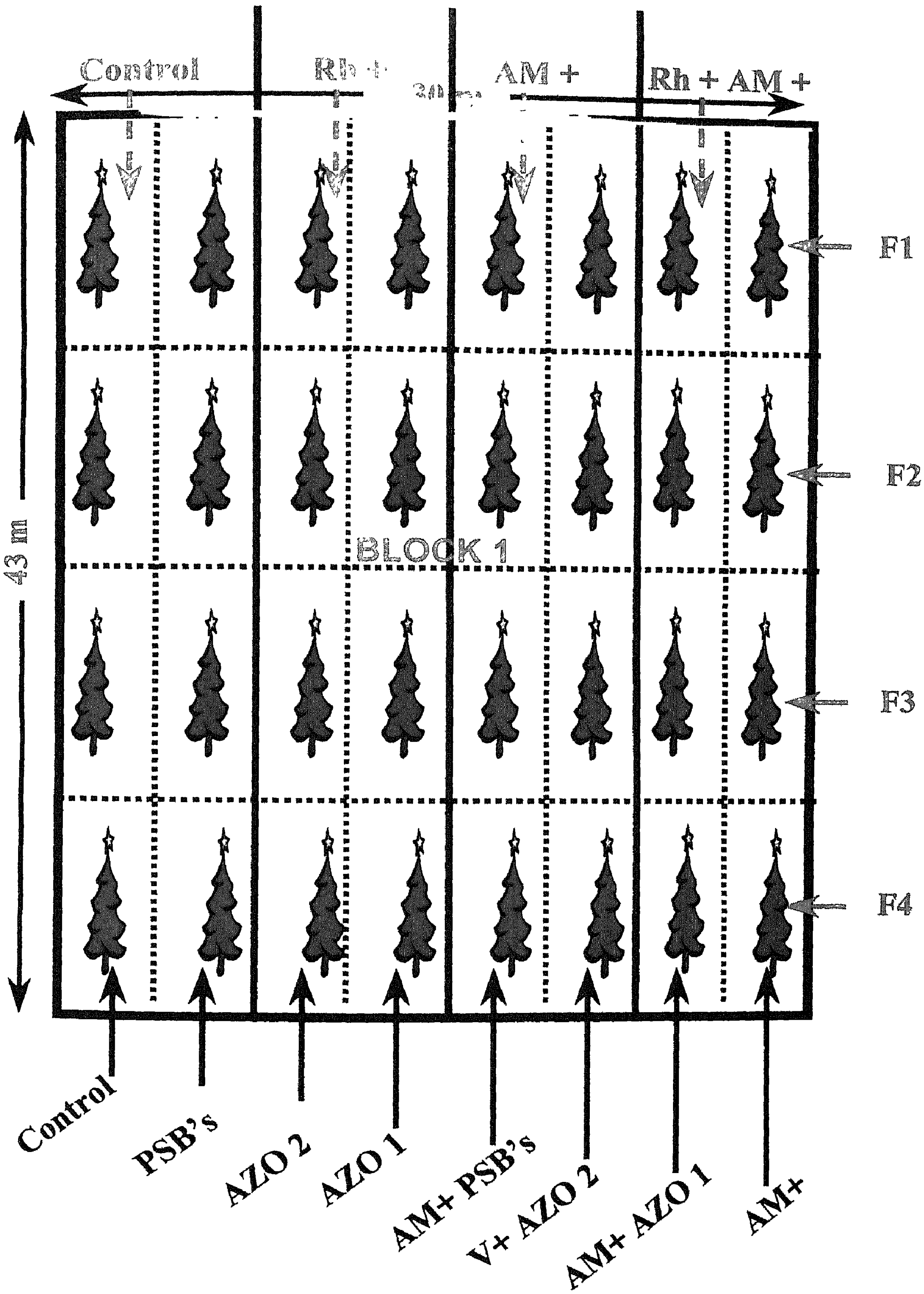
Annexure - O

Layout of a representative block wheat (2nd rotation) trial at Gual Pahari



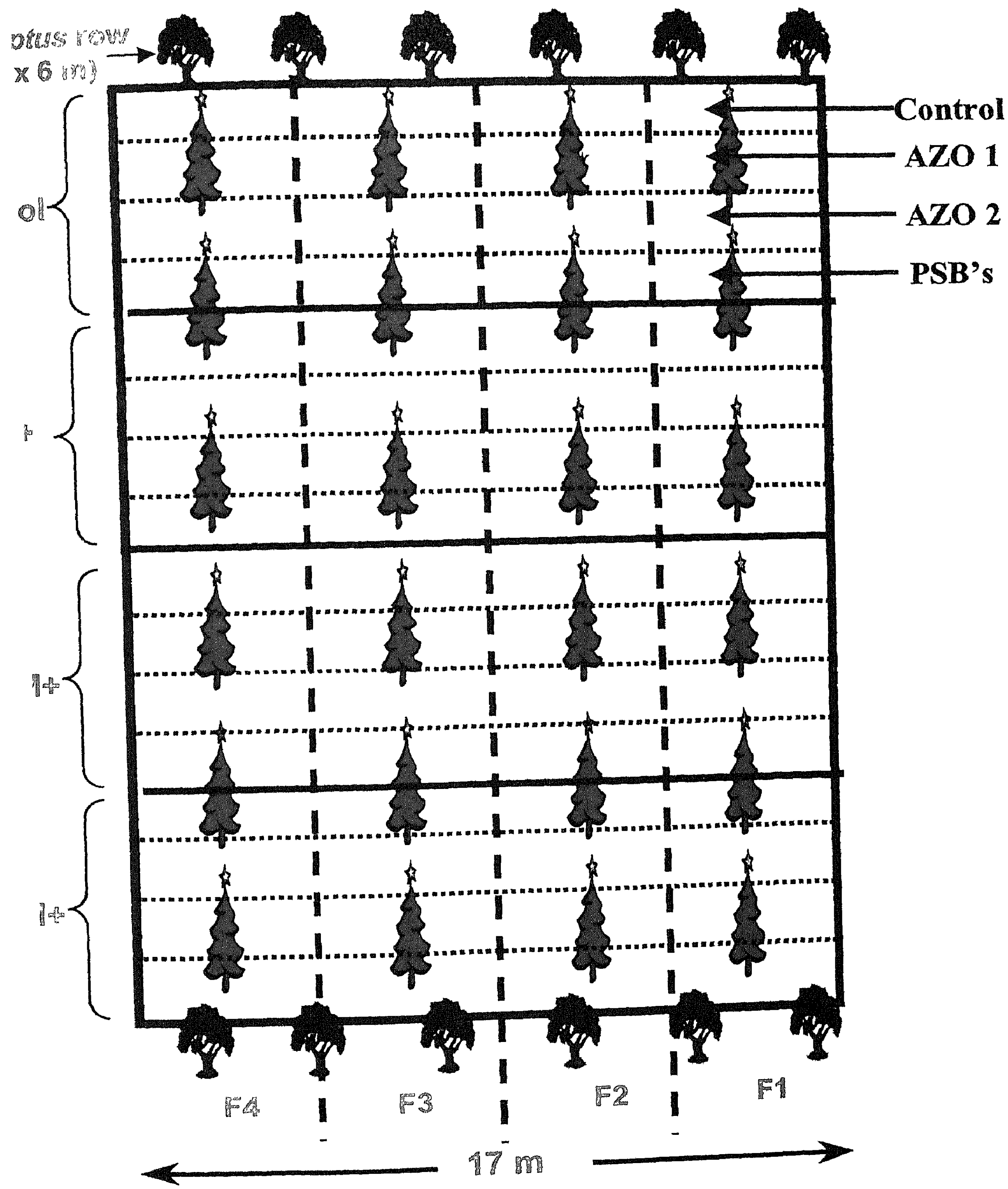
Annexure - P

Layout of a representative block for wheat (2nd rotation) trial at Badshahpur, Haryana



Annexure - Q

Layout of a representative block urd (2nd rotation) trial at Gual Pahari

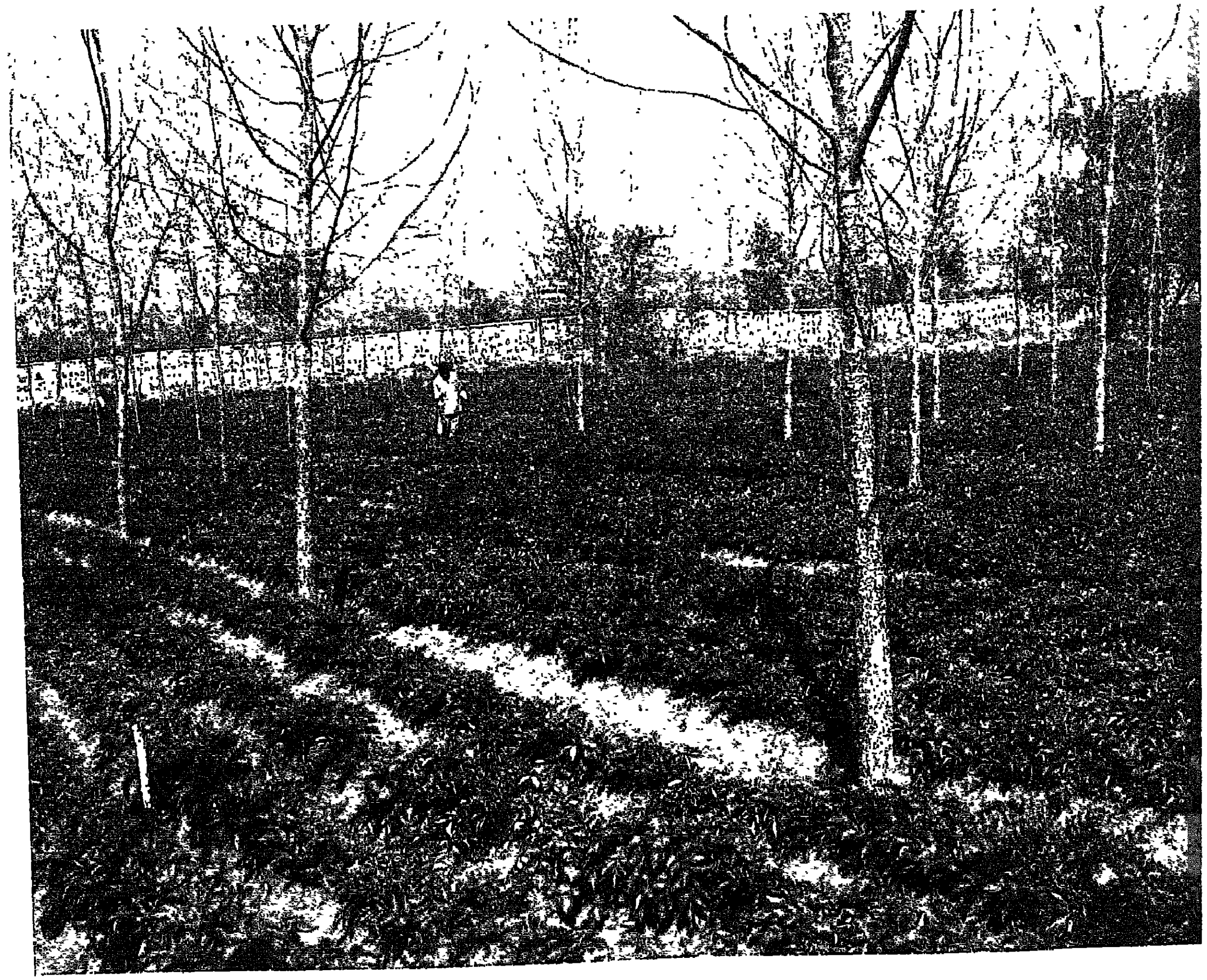


Annexure - R

Site view after urd harvest… at Gual Pahari

Annexure - S

Potato with poplars... at Gual Pahari



Conclusions

The rotation of wheat pulses subject to various inoculations and residual advantages have amply shown the significance of such efforts through appropriate management practices. Validation trials followed by pro-active extension initiatives can eventually help making redical changes in the agricultureal practices without major operational changes. This would enable the economic benefits and all round improvement in Indian agriculture.